JULY 1956

Journal
of
The Franklin Institute

1826

1956

Philadelphia and the Development of the Motion Picture
THOMAS COULSON

Plasma Fluctuations in Crossed Electric and Magnetic Fields
H. W. BATTEN, H. L. SMITH AND H. C. EARLY

Analysis of Magnetic Circuits with Given D-c. Excitation
EVERETT H. MITCHELL

Non-Uniform Torsion of Tapered I-Beams
LAWRENCE H. N. LEE

The Academy Bell: The Franklin Institute and Old Philadelphia
JOSEPH SAMUEL HEPBURN

Annual Report of the Board of Managers for the Year 1955

Franklin Institute:
Research Notes
Department Reports
Museum Notes
Book Reviews
Current Topics
NBS Notes

VOL. 262 NO. 1

As a Direct-Reading Instrument *The extreme sensitivity of the d-c amplifier is utilized to check plasticizer insulation resistance values in the megamegohm range.*

As a Recorder Preamplifier *The rack-mounted amplifier above is being used to increase the sensitivity of a recorder in running special tests of switches.*

As a Null Detector *The d-c Amplifier is being used above for factory checking and calibration of instruments.*

L&N Low Level d-c Amplifiers are

Triple Purpose... for Triple Service

● In response to the constant demand for versatility in precision instruments, these d-c Indicating Amplifiers combine the functions of three useful instruments in one:

1. A Direct-Reading Instrument that is always ready to use . . . never any readjusting of zero, either initially or during a series of readings. Simply select the range in which you want to work by turning scale-multiplier knob.

2. A Recorder Preamplifier — Values measured by Stabilized d-c Amplifiers can be recorded directly on Speedomax recorders.

3. A Null Detector more sensitive than most reflecting galvanometers, yet with full scale response time of only 2 to 3 seconds. These instruments are unaffected by vibration; leveling is not necessary. At the turn of a range knob, a wide choice of sensitivities can be obtained without external shunts. A non-linear response characteristic is also available for easy balancing.

These amplifiers are suitable for handling low level measurements with thermocouples, strain gages, bolometers—bridge and potentiometer circuits—ionization, leakage and phototube currents—almost any measurement of extremely small direct current or voltage.

Self-contained, the unit can either be used "as is" or removed from case and mounted on a 19" relay rack.

For details, including complete specifications, send for Folder EM9-51(1). Write our nearest office, or 4992 Stenton Ave., Phila. 44, Penna.

LEEDS & NORTHRUP

instruments · automatic controls · furnaces

Journal
of
The Franklin Institute

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

EDITOR, HENRY BUTLER ALLEN, MET.E., D.Sc., Sc.D., D.ENG.

ASSISTANT EDITOR, NANCY S. GLENN, M.A.

ASSOCIATE EDITORS:

CHARLES B. BAZZONI
CHARLES L. CRITCHFIELD
RUPEN EKSERGIAN
VIRGIL MORING FAIRES
PAUL D. FOOTE
WALTER C. JOHNSON
ROBERT S. LIVINGSTON
C. E. K. MEES
WILLIAM B. MELDRUM
ARTHUR L. DAY, *Emeritus*
F. J. MURRAY
FREDERICK SEITZ
W. F. G. SWANN
HUGH S. TAYLOR
MERLE A. TUVE

COMMITTEE ON PUBLICATIONS:

LIONEL F. LEVY, CHAIRMAN
HENRY B. ALLEN
G. H. CLAMER
GAYLORD P. HARNWELL
RICHARD HOWSON
C. L. JORDAN

VOL. 261.—Nos. 1561–1566

(131st Year)

JANUARY–JUNE, 1956

PHILADELPHIA

THE FRANKLIN INSTITUTE

Benjamin Franklin Parkway at 20th Street

1956

LANCASTER PRESS, INC., LANCASTER, PA

INDEX TO ADVERTISERS

	PAGE
Ajax Electric Company	ii
Almo Radio Co.	x
Atlas Photo Engraving Co.	xiii
Bell Telephone Laboratories	vi
Biddle Co., James G.	xi
Bolger-Parker Co.	xiii
Buten, M. & Sons	x
Coleman, W. B., & Co.	xii
Damon & Foster	xii
Davidson, P. L.	xii
Eggly-Furlow Engineers	xii
Fehr & Johnson, Inc.	xiii
Fidelity-Philadelphia Trust Co.	xiv
Franklin Institute, Journal	viii
Franklin Institute, Laboratories	Fourth cover page
Franklin Institute, Membership	Third cover page
Harris-Dechant Associates	xii
Herbach & Rademan	xiii
Hess & Barker	xi
Kearney Lumber Co.	xiii
Lancaster Press, Inc.	ix
Leeds & Northrup Co.	Second cover page
Leopold, Charles S.	xii
Levy & Co., Max	x
Shanahan & Co.	xiii
Steinberg and Company, Albert	xi
Thomas Co., Arthur H.	x
Yarnall-Waring Co.	ix

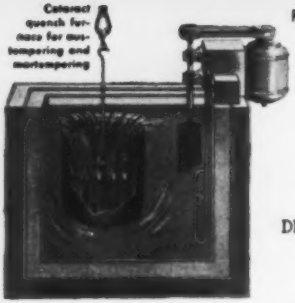
Entered as second-class matter March 14, 1928, at the post office at Lancaster, Pa., under act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph (d-2), section 34.40, P. L. & R. of 1948, authorized on July 3, 1919.

Suspended-electrode type furnace

AJAX

Salt Bath Furnaces

Cutaway quench furnace for austempering and martempering



For any of these applications . . .

ALUMINIZING
ANNEALING
AUSTEMPERING
BRAZING
CARBURIZING
CLEANING
CYANIDE HARDENING
CYCLIC ANNEALING
DESCALING . . . DESANDING
DRAWING
HARDENING
HEATING FOR
FORGING AND FORMING
MARTEMPERING
SOLUTION HEAT TREATING

FREE! SALT BATH HEATING TIME CALCULATOR FOR STEEL. Handy slide chart. Write on company stationery.

Write for Details including actual case history data for any job.

AJAX ELECTRIC COMPANY

Philadelphia 23, Pa.

Associated Companies: Ajax Electric Furnace Corp. • Ajax Electrothermic Corp. • Ajax Engineering Corp.

THE FRANKLIN INSTITUTE

1956

OFFICERS

President ..... S. WYMAN ROLPH
Executive Vice-President ..... JOHN S. BURLEW
Vice-Presidents ..... G. H. CLAMER; JAMES H. ROBINS; MORTON GIBBONS-NEFF; W. LAURENCE LEPAGE; CLARENCE L. JORDAN
Secretary ..... HAMILTON VAUGHAN BAIL
Treasurer ..... HAMILTON VAUGHAN BAIL
Assistant Secretary ..... JOHN FRAZER
Assistant Secretary ..... CECIL M. WATERBURY
Assistant Treasurer ..... CECIL M. WATERBURY

BOARD OF MANAGERS

Term expires in 1957	*Term expires in 1958*	*Term expires in 1959*
EDWARD G. BUDD, JR.	HENRY B. BRYANS	HENRY B. ALLEN
JOHN S. MALICK	FRANCIS J. CHESTERMAN	A. FELIX DUPONT, JR.
JAMES MCGOWAN, JR.	JAMES CREESE	J. G. RICHARD HECKSCHER
RICHARD T. NALLE	RUPEN EKSERGIAN	RALPH KELLY
CHARLES S. REDDING	W. H. FULWEILER	LIONEL F. LEVY
JOHN RUSSELL, JR.	GAYLORD P. HARNWELL	CHARLES PENROSE
W. MAXWELL SCOTT, JR.	HAROLD S. LEDUC	R. G. RINCLIFFE
	EMERY W. LOOMIS	PHILIP H. WARD, JR.

GEORGE WHARTON PEPPER, Honorary Member of the Board

The following are *ex-officio* members of the Board of Managers: President, Executive Vice-President, Vice-Presidents, Secretary, Treasurer, Chairman of the Committee on Science and the Arts and Chairman of the Library Committee.

EXECUTIVE COMMITTEE OF THE BOARD OF MANAGERS

G. H. CLAMER, *Chairman*
CHARLES S. REDDING, *Vice-Chairman*
JOHN S. BURLEW — RICHARD T. NALLE — S. WYMAN ROLPH

STANDING COMMITTEES OF THE BOARD OF MANAGERS

Committee on Board Vacancies ..... CHARLES S. REDDING, *Chairman*
Budget Committee ..... JAMES H. ROBINS, *Chairman*
Personnel Policy Committee ..... J. G. R. HECKSCHER, *Chairman*
Vermilye Medal Committee ..... RALPH KELLY, *Chairman*

COMMITTEES OF THE INSTITUTE

Bartol Research Foundation Committee ..... G. H. CLAMER, *Chairman*
Biochemical Research Foundation Committee ..... A. FELIX DUPONT, JR., *Chairman*
Committee on Science and the Arts ..... FRANCIS B. FOLEY, *Chairman*
Endowment Committee ..... MORTON GIBBONS-NEFF, *Chairman*
Finance Committee ..... BRANDON BARRINGER, *Chairman*
Library Committee ..... PENROSE HOOPES, *Chairman*
Meetings Committee ..... ———, *Chairman*
Membership Committee ..... MORTON GIBBONS-NEFF, *Chairman*
Museum and Memorial Committee ..... I. MELVILLE STEIN, *Chairman*
Publications Committee ..... LIONEL F. LEVY, *Chairman*
Committee on Research ..... G. H. CLAMER, *Chairman*

The President and the Executive Vice-President are *ex-officio* members of all Committees of the Institute.

HOSTESS COMMITTEE OF THE INSTITUTE

MRS. THOMAS D. THACHER, *Chairman*

ADMINISTRATIVE STAFF OF THE FRANKLIN INSTITUTE

Executive Vice President and Director ..... JOHN S. BURLEW
Secretary and Treasurer ..... HAMILTON VAUGHAN BAIL
Assistant Treasurer ..... *CECIL E. WATERBURY
Controller ..... S. J. CLEVENGER
Assistant to the Executive Vice President ..... W. F. JACKSON, JR.
Director of Endowment ..... W. F. JACKSON, JR.
Director of Meetings ..... JAMES BARNES
Director of Membership ..... MRS. MILTON PRICE HARLEY
Director of Public Relations ..... ALBERT D. HOLLINGSWORTH
Secretary, Committee on Science and the Arts ..... *JOHN FRAZER

JOURNAL

Editor ..... JOHN S. BURLEW
Managing Editor ..... MRS. ROBERT C. GLENN

LIBRARY

Librarian ..... WALTER A. R. PERTUCH
Assistant Librarian ..... MISS R. A. APPLEGATE

MUSEUM

Director of Museum ..... A. C. CARLTON
Director of Planetarium ..... I. M. LEVITT
Assistant Director of Planetarium ..... J. W. STREETER
Director of Museum Education ..... MRS. GLORIA C. GOSSLING
Director of Museum Research ..... THOMAS COULSON
Project Engineer ..... PHILIP ALLEN
Assistant for Museum Services ..... MRS. J. J. HEATH
Assistant for Exhibits ..... MRS. ROBT. N. YARNALL, JR.

PERSONNEL AND SERVICES

Director of Personnel and Services ..... JOHN E. CHRIST
Building Superintendent ..... J. E. MARCANTUONO
Building Engineer ..... JOHN MOORE
Purchasing Agent ..... J. H. JACKSON
Mail Room Supervisor ..... MRS. ANNA M. MULVANEY

* *Also has appointment as* Assistant Secretary.

ADMINISTRATIVE STAFF OF THE FRANKLIN INSTITUTE

LABORATORIES FOR RESEARCH AND DEVELOPMENT

Director of Laboratories	Nicol H. Smith
Assistant to Director (*Business Admin.*)	P. F. Suffredini
Assistant, Information Services	E. H. Nelson, Jr.
Assistant to Director (*Project Development*)	Morison Blake
Assistant to Director (*Project Development*)	Wm. M. Morsell
Foreman of Machine Shop	Leo J. Streletz
Associate Director (*Electrical Engineering*)	Lewis P. Tabor
Chief, Aeronautics	Ralph S. Barnaby
Chief, Analysis	Donald B. Houghton
Chief, Electromechanics	Richard W. Pitman
Chief, Electronics	Alan C. Byers
Chief, Engineering Psychology	Ezra S. Krendel
Chief, Power & Control	Bruce B. Young
Associate Director (*Chemistry and Physics*)	Carl T. Chase
Chief, Bioengineering	Wallace E. Frank
Chief, Chemical Kinetics & Spectroscopy	Wm. E. Scott
Chief, Colloids	Edmund Thelen
Chief, Engineering Physics	Edward E. Hannum
Associate Director (*Mechanical Engineering*)	Frank S. Chaplin
Chief, Engineering Mechanics	Axel O. Bergholm
Chief, Friction & Lubrication	D. D. Fuller
Chief, Machine Design & Development	Wm. W. Dickhart, III
Chief, Nuclear Power	Francis L. Jackson
Acting Chief, Applied Hydraulics	Francis L. Jackson
Associate Director (*Solid State Physics*)	———
Asst. to Assoc. Director	Raymond S. Dalter
Chief, Metallurgy	Raymond L. Smith
Chief, Physics of Metals	Frank E. Jaumot, Jr.
Acting Chief, Magnetics	Frank E. Jaumot, Jr.

BARTOL RESEARCH FOUNDATION (Swarthmore, Penna.)

Director	W. F. G. Swann
Assistant Director	W. E. Danforth
Assistant Director	C. E. Mandeville

The Franklin Institute acts as Trustee for
the *Biochemical Research Foundation* (Newark, Del.)
William G. Batt, Director

Transistorized telephone summons you with a musical tone

Above: Experimental model resembles regular "500" set; the only visible departure is a louver in the base through which the musical tone is radiated.

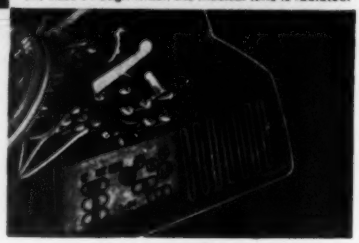
Bell scientists have developed a new musical tone device which may some day replace the telephone bell, if it meets technical standards and customers' approvals.

Because the musical tone equipment uses transistors, the tones will be transmitted with the same amount of power required to transmit a telephone conversation—considerably less than is needed to make a telephone bell ring.

The experimental telephone sets resemble the current "500" sets; the only external difference is a louver at the side of the base through which the tone is radiated by a small loudspeaker mounted inside the telephone's base.

Tests have shown that the musical tone can be heard at great distances. It stands out above general room noise and can be distinguished from such sounds as ringing of doorbells, alarm clocks, and home fire alarms.

This new low-power signaling technique is expected to play an important part in the electronic switching system now under development at Bell Telephone Laboratories.



Above: Bell ringer has been displaced by a small loudspeaker in transistorized telephone. Left: L. A. Meacham heads the team of engineers that developed the musical tone ringer. Mr. Meacham holds a B.S. in Electrical Engineering from the University of Washington, Class of '29. He became affiliated with Bell Labs a year after his graduation. In 1939 Mr. Meacham won the "Outstanding Young Electrical Engineer" award of Eta Kappa Nu.

BELL TELEPHONE LABORATORIES

World center of communications research and development

Journal
of
The Franklin Institute

EDITOR, JOHN S. BURLEW
MANAGING EDITOR, NANCY S. GLENN
Editor Emeritus, HENRY B. ALLEN

Associate Editors:

CHARLES B. BAZZONI
CHARLES L. CRITCHFIELD
RUPEN EKSERGIAN
VIRGIL MORING FAIRES
PAUL D. FOOTE
WALTER C. JOHNSON
ROBERT S. LIVINGSTON
C. E. K. MEES
WILLIAM B. MELDRUM
ARTHUR L. DAY, *Emeritus*
F. J. MURRAY
FREDERICK SEITZ
W. F. G. SWANN
HUGH S. TAYLOR
MERLE A. TUVE

Committee on Publications:

LIONEL F. LEVY, *Chairman*
HENRY B. ALLEN
G. H. CLAMER
GAYLORD P. HARNWELL
RICHARD HOWSON
CLARENCE L. JORDAN

Vol. 262 **JULY, 1956** **No. 1**

CONTENTS

Philadelphia and the Development of the Motion Picture ..... THOMAS COULSON 1

Plasma Fluctuations in Crossed Electric and Magnetic Fields ..... H. W. BATTEN, H. L. SMITH AND H. C. EARLY 17

Analysis of Magnetic Circuits with Given D-c. Excitation ..... EVERETT H. MITCHELL 31

Non-Uniform Torsion of Tapered I-Beams ..... LAWRENCE H. N. LEE 37

The Academy Bell: The Franklin Institute and Old Philadelphia ..... JOSEPH SAMUEL HEPBURN 45

Notes from the National Bureau of Standards 53

The Franklin Institute

- Annual Report of the Board of Managers for the Year 1955 57
- Committee on Science and the Arts 71
- Journal of The Franklin Institute 71
- Membership 72
- Library 72
- Publications Received 76
- Notes from The Franklin Institute Laboratories for Research and Development 77
- Notes from The Franklin Institute Museum 79
- Notes from the Biochemical Research Foundation 81

Book Reviews 85

Current Topics 88

Published monthly by The Franklin Institute of the State of Pennsylvania, Benjamin Franklin Parkway at Twentieth St., Philadelphia 3, Pennsylvania. Printed by Lancaster Press, Inc., Prince and Lemon Sts., Lancaster, Pennsylvania.

Subscription rates: Domestic, $10.00 a year; Foreign, $11.00 a year. Single current issues, $1.00. Reprints, 50 cents per installment. All inquiries regarding subscriptions, change of address, sale of back issues and reprints, should be addressed to the Philadelphia office.

Indexes to the semi-annual volumes of the JOURNAL are published in the June and December numbers.

Copyright © 1956, by The Franklin Institute of the State of Pennsylvania.

Announcing publication of

The Proceedings of the Symposium on

EARTH SATELLITES AS RESEARCH VEHICLES

Held April 18, 1956

AT THE FRANKLIN INSTITUTE

The following papers are included, together with discussion of each:

The International Geophysical Year Earth Satellite Program
HOMER E. NEWELL, JR.

Astronautical and Space-Medical Research with Automatic Satellites
KRAFFT A. EHRICKE

The Moon Rocket ..... GEORGE H. CLEMENT

Astrophysical Research with an Artificial Satellite
LYMAN SPITZER, JR.

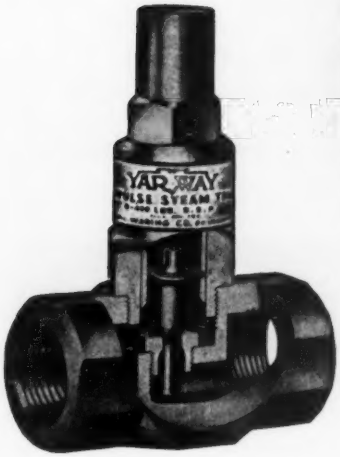
The Effect of the Earth's Oblateness and Atmosphere on a Satellite Orbit ..... JOHN DE NIKE

"Astro" (Artificial Satellite Time and Radio Orbit)
LOVELL LAWRENCE, JR.

Recovery of Data in Physical Form ..... R. W. PORTER

Issued as Monograph No. 2 under the auspices of the JOURNAL OF THE FRANKLIN INSTITUTE, the volume is now available. Send your order (at $2.50 for each copy) to

JOURNAL OF THE FRANKLIN INSTITUTE
20th and the Parkway
Philadelphia 3, Pa.



YARWAY
impulse
steam trap

- Quick Heating
- Small Size
- One Moving Part
- Low Price
- Stainless Steel Construction

MORE THAN A MILLION SOLD

Known throughout industry as the steam trap that "gets equipment hot in a hurry and *keeps it hot.*" Free on request, Yarways 24-page booklet on steam traps and trapping problems. Ask for Bulletin T-1740.

YARNALL-WARING COMPANY
132 Mermaid Ave., PHILADELPHIA 18, PA.

A COMPLETE PRINTING SERVICE

GOOD PRINTING does not just happen; it is the result of careful planning. The knowledge of our craftsmen, who for many years have been handling details of composition, printing and binding, is at your disposal. For over seventy-five years we have been printers of scientific and technical journals, books, theses, dissertations and works in foreign languages. Consult us about your next job.

. PRINTERS OF .
JOURNAL OF THE
FRANKLIN INSTITUTE

LANCASTER PRESS, Inc.
PRINTERS • BINDERS • ELECTROTYPERS
ESTABLISHED 1877 LANCASTER, PA.

PRECISION RULINGS ON GLASS

Scales · Grids · Reticles
Halftone Screens

MAX LEVY & CO. · Wayne Ave. & Berkley St. Phila., Pa.

Almo RADIO COMPANY
Executive Offices & Warehouse
412-16 N. SIXTH STREET · PHILADELPHIA 23 · PA.

9 LOCATIONS TO SERVE YOU

Executive Offices: 412 N. 6th Street, Phila. 23, Pa.

7540 FRANKFORD AVE.	509 ARCH ST.	6205 MARKET ST.	NORRISTOWN, PA.
PHILA. 36, PA.	PHILA. 6, PA.	PHILA. 39, PA.	550 MARKLEY ST.
DE 2-2234	WA 2-5153	AL 4-1706	Norristn. 8-7580
ATLANTIC CITY, N.J.	CAMDEN, N.J.	SALISBURY, MD.	WILMINGTON, DEL
4401 VENTNOR AVE.	1133 HADDON AVE.	317 PARK HEIGHTS AVE.	1122 FRENCH ST.
At. City 2-5928	EM 5-1960	Salisbury 2-3193	Wilm. 5-5168

EVERYTHING IN PAINTS

BUTEN'S

PAINT STORES

Phila., Chester, Reading, Upper Darby, Bryn Mawr, Darby, Doylestown
Camden, N. J. — Wilmington, Del.

ARTHUR H. THOMAS COMPANY

Laboratory Apparatus and Reagents

Selected for Chemistry and Biology

Adequate stocks of 16,000 Apparatus items and 6,000 Reagent items carried in our Warehouse stock for immediate shipment

WEST WASHINGTON SQUARE PHILADELPHIA 5, PA.

BIDDLE
Instruments

and miscellaneous laboratory equipment cover a wide field of electrical, mechanical and scientific testing, measuring and experimental work.

For a complete file of all our products write for Bulletin 19-53

JAMES G. BIDDLE CO.
Electrical & Scientific Instruments
1316 Arch Street—Philadelphia 7, Pa.

59 YEARS OF EXPERIENCE
ENGINEERING MACHINISTS
DESIGN • MANUFACTURE • REPAIRS
HESS & BARKER
212-22 S. Darien St. • WAlnut 3-0248 • Philadelphia 7, Pa.

We specialize in supplying *your* needs . . .

From basic parts—such as resistors, tubes, condensers, and transformers—
To newer developments—such as vectors, turret assemblies, transistors, and germanium crystal diodes

FREE PARKING

ALBERT STEINBERG AND COMPANY
2520 N. Broad St., Philadelphia BA 3-9400
Greater Northeast 6324 Sackett St., Philadelphia JE 3-2994

Consulting Engineers

HARRIS-DECHANT ASSOCIATES
Fidelity-Philadelphia Trust Building
Philadelphia, Pa.

FREDERIC R. HARRIS, INC.
27 William Street New York, N.Y.
Consulting Engineers
Naval Architects

EGGLY-FURLOW ENGINEERS
Consulting Engineers
PHILADELPHIA 2, PA.
1500 Walnut Street
Telephone: PEnnypacker 5-1197

DAMON & FOSTER
Consulting Engineers
Surveyors
CHESTER PIKE & HIGH ST.
SHARON HILL, PA

CHARLES S. LEOPOLD
Consulting Engineer
213 SOUTH BROAD ST.
PHILA. 2, PA

P. L. DAVIDSON
Consulting Engineer
Philadelphia, Pa. and
Greensboro, N. C.

W. B. COLEMAN & CO.
Metallurgists - Chemists - Engineers
Spectrographic and Spectrophotometric Analysis
Chemical and Physical Testing—Microscopic Investigation
Huey and Salt Spray Corrosion Tests—Boiler Water Conditioning
9TH & RISING SUN AVE., PHILADELPHIA 40, PA.

Commercial Stationery
Loose Leaf — Blank Books
Filing Equipment
Office Supplies

SHANAHAN & CO.

22 S. 18 St. Ri 6-0333

WHERE QUALITY OF REPRODUCTION IS ESSENTIAL...
BUT ECONOMY IS IMPORTANT...

The answer is Atlas
Photo Engraving Co
1208 Cherry Street Philadelphia, Pennsylvania

BOLGER-PARKER COMPANY
Hauling and Rigging Contractors
752 N. MARKOE ST.
PHILADELPHIA 39, PA.
RESIDENCE PHONES
HILLTOP 6-3731
BROADWAY 5-3912
BUSINESS PHONE
BARING 2-8174

Franklin Institute Books
are bound by

FEHR & JOHNSON, INC.

Fine Bookbinding

831 Cherry Street
Philadelphia 7, Pa.

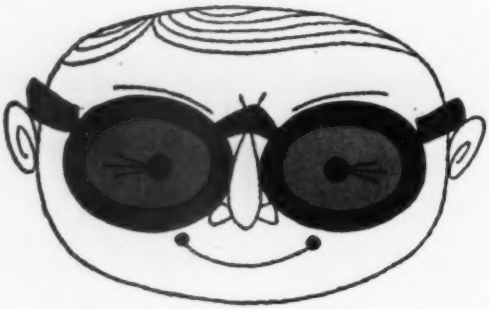
HEADQUARTERS
FOR
RADIO PARTS ELECTRONIC COMPONENTS
GEIGER-MULLER COUNTER TUBES
AND
RADIO ACTIVITY DETECTORS

HERBACH & RADEMAN
1204 ARCH STREET PHILADELPHIA 7, PA.

KEARNEY LUMBER COMPANY

Lumber of every description for every purpose

2916-26 Kensington Ave.
GA 6-5720 Phila., Pa
"Our Fleet of Trucks Deliver Anywhere"



Rose-Colored Glasses

Anybody who thinks he doesn't need a will—that somehow his estate will be distributed fairly and his family will be taken care of—is looking at the future through rose-colored glasses. The truth is that if you leave no will, the law will distribute your estate—in a way that could be quite different from what you want. Don't take chances. See your lawyer. Write a will. And name Fidelity the executor and trustee so as to insure the most satisfactory handling.

FIDELITY-PHILADELPHIA TRUST COMPANY

Bankers since 1866

Broad and Walnut Streets
Philadelphia 9

15 additional offices in Philadelphia and Delaware County

Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 262 JULY, 1956 No. 1

PHILADELPHIA AND THE DEVELOPMENT OF THE MOTION PICTURE

BY

THOMAS COULSON[1]

"The photographs were made at 1206 Chestnut Street, in the studio of Mr. O. H. Willard, which place may now be well named the Cradle of the Motion Picture."

In view of the generally accepted belief that Thomas Alva Edison was the inventor of the motion picture it may come as a surprise to learn that these words are quoted from the program of a demonstration of moving pictures given in the Philadelphia Academy of Music in the year 1870, when Edison was a young man of twenty-three, and still occupied with the mysteries of the electric telegraph.

The motion picture as we know it today consists of a complex combination of parts centering upon a sensitized film, a camera to expose the film, a projector and a powerful source of illumination. We omit any reference to the artistic element contributed by the actor and director. Each of the essential elements is the product of a series of sciences—chemistry, mechanics, optics, etc. To ascribe to any one person the invention of the requisite combination is impossible, but a group of Philadelphians played a very significant part in assembling the necessary features that resulted in the development of the motion picture as a source of instruction and entertainment.

Let us not begin with the imputation that the earliest impulses originated in this American city. We have to move back three hundred years to the time when a Jesuit priest called Athanasias Kircher described the *Magia Catoptria*, which was the first magic lantern (1).[2] Forward from that time the magic lantern underwent continuous improvement as lenses and illuminants progressed. After this device

[1] Director of Museum Research, The Franklin Institute, Philadelphia, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.

had released pictures from the immobility of paint and canvas there arose a natural desire to endow them with the fluidity of movement. The obstacles were immense and could only be overcome when science had made advances in other directions. Peter Mark Roget (of *Thesaurus* fame) advanced a theory of the persistence of vision, a phenomenon of vital significance in the later motion picture machine. Profiting by this theory, Plateau in Ghent, and Stampfer in Vienna simultaneously produced machines by which it was possible to study the motion of a vibrating body by examining it through equidistant slits in a rotating disc. These devices could be used only by one pair of eyes at a time.

William George Horner, an Englishman, converted the device from a vertical disc to a horizontal hollow cylinder with slots pierced in the side, and the picture to be viewed was coiled around the inside of the cylinder. The motion could then be viewed by as many pairs of eyes as could conveniently be grouped around the device. This instrument, called the Fantascope by its inventor, attained a worldwide popularity under several other names, best known of which were the Zoetrope and the Wheel of Life. Although it was introduced in 1834 it may still be found in toy-shops.

The next advance was made in Vienna, where Baron Von Uchatius combined Stampfer's rotating disc with Kircher's magic lantern, and was able to project hand-drawn pictures on to a screen and to give them apparent motion. This took place in 1853, and from that time there were numerous improvements upon the projection of hand-drawn pictures, with or without motion. This was followed by a hiatus until progress had been made in another field, which brings our story to a Philadelphia *locale* and the introduction of photography.

Members of The Franklin Institute had displayed the liveliest curiosity in photography from the time of its inception, and its JOURNAL had been responsible for promoting its adoption by publishing the first account in this country of the Daguerre process (**2**). A member of the Institute, Joseph Saxton, is credited with making the first outdoor photograph in the United States, a picture taken from the Mint, where he was employed. It should be observed, in the projection of photographs, there was not yet any satisfactory method of making transparent positives from Daguerrotypes.

In 1840, William and Frederick Langenheim opened a photographic studio at the Merchant's Exchange in Philadelphia, advertising that they would make pictures from the size of a pea to very large ones. The Langenheims were not the first professional photographers but they were pioneers in the photography of natural subjects. In 1850, they were responsible for a minor contribution toward the development of the motion picture with their Hyalotype process (**3**). Having obtained a camera from Vienna they made pictures of scenery which

could be projected on a screen by means of a magic lantern equipped with a gas flame.

There is no evidence that the Langenheims combined the glass lantern slides with Plateau's or Stampfer's discs to obtain an effect of motion, but in the year they patented their Hyalotype process they developed an instrument which was the protype of Edison's peep-show movies and which, we rather surmize, suggested the next step toward the accomplishment of the modern motion picture by photography. Among their other accomplishments the Langenheims did a great deal to popularize the stereoscope. About the year 1850 they began making and selling stereoscopic views in large quantities. In order that they might derive the maximum profit from their enterprise, they opened the "Stereoscope Cosmorama" at 188 Chestnut Street. This was a collection of peep-show machines by which a spectator could see one stereoscopic view after another by turning a crank.

We suspect that this machine conveyed a suggestion to one of its more intelligent observers, Coleman Sellers, who was Professor of Mechanics at The Franklin Institute school, and later held the office of President of the Institute.

Sellers was a fruitful inventor of mechanical devices and an enthusiastic amateur photographer. He had acquired distinction for his efforts to simplify the amateur's problems in the production of a portable dark-room and, what was more important, the glycerine bath for preventing the photographic plate from drying between exposure and development (only wet plates were available in those days). Sellers was also a member of the firm of William Sellers and Company, makers of machine tools, hoists, cranes, presses, etc. As an accomplished photographer Coleman Sellers was dissatisfied with the ambrotypes used to illustrate the firm's advertising literature and he wished to see them replaced by photographs. He was instrumental in having a photographic studio installed in the drafting room and in having the firm's apprentices made familiar with the processes employed in it. However, he must, at times, have wished that he had some means by which he could show prospective customers pictures of the mechanisms in motion.

Sellers was not the type of man who perceives the need for a thing without doing something to fulfil the need. In 1860 he applied himself to the problem and, in the following year, he obtained a patent for an instrument he called the Kinematoscope (4), thereby introducing to the science a word that came into general use all over the world.

The original Kinematoscope is displayed in the Institute's Museum, the gift of the inventor's sons. It comprises a cylinder with a binocular eyepiece containing stereoscopic prisms, with a shield to exclude light. The cylinder has two opposite segments cut away to allow light to fall upon the pictures. Within the cylinder is a series of wings radiating from a central spindle. The pictures were attached to these wings and

the whole series was made to rotate by turning a crank. Around the wings is a radial band of tin, pierced with slits about one inch long and $\frac{3}{8}$ of an inch wide. The pictures are viewed through these slits as they are turned.

Sellers' Kinematoscope, 1860.

Sellers only arrived at his final design after trying several cut-off devices that would render the instantaneous images he desired, but he was troubled by a blurring of the image that prevented a clear sight of the details. He ultimately arrived at the opinion "it is absolutely necessary to bring the picture to rest during the moment of vision."

Sellers was using photographic fidelity to perform what makers of the Wheel of Life had only been able to do with hand-drawn figures. He was unable to photograph continuous movement, for he was compelled to work with sensitized glass plates that required a long exposure. He had, therefore, to analyze the motion he proposed to capture, and then to reproduce it by synthesis. He made the analysis with a stereoscopic camera. The first experiments were made with his two young sons. The elder boy was to engage in hammering a nail, while the younger was to rock in his nursery chair. Since the identity of these two early motion picture actors may be more clearly defined, Coleman junior, the hammer wielder, was later head of the William Sellers Company, and his younger brother, Horace, became a well known architect.

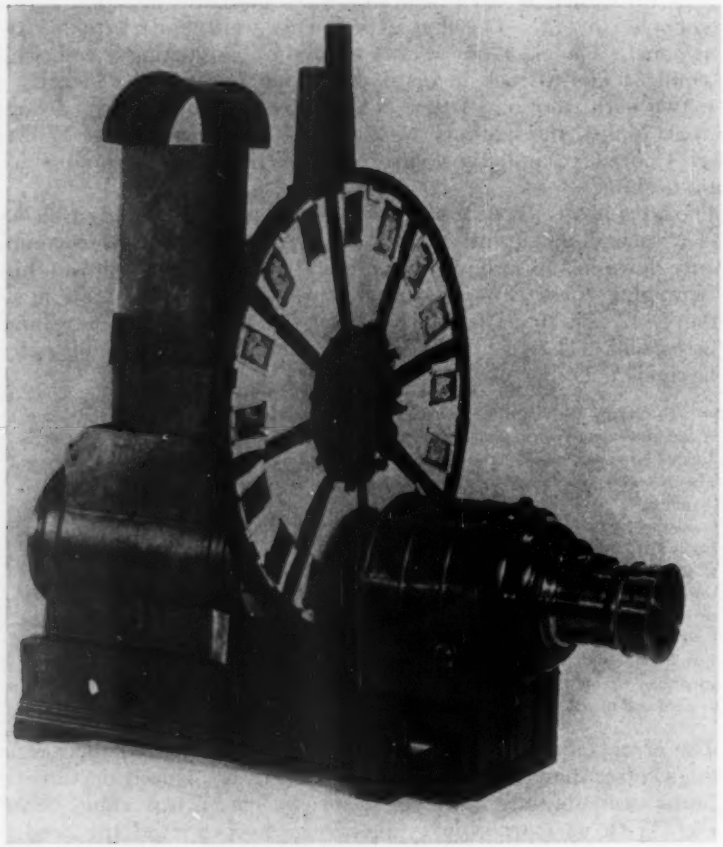
The boys had to be posed for each time exposure. Young Coleman stood with hammer up-raised in the first of these; with the hammer halfway down in the second exposure, and hitting the nail in the third. By arranging these three in reverse order, the upward motion was synthetized. The motions of Horace in the rocking chair were made to correspond. Here is how Sellers explained his methods in his patent application:

> To prepare the pictures for this instrument it is necessary to consider the nature of the movement it is designed to represent and with this in view motions must be divided into two general classes, under the name of reciprocating and rotary motions. The first class, or the reciprocating motion, comprises all simple motions, such as "fanning," "pounding," "sawing," "planing," "rocking," and in fact all motions consisting of two extreme positions, and the intermediate positions the same in the backward or forward motion; while the second class, or rotary motion, comprises all motion in a series of which no two positions are the same until the completion of the series. To prepare a subject under the head of the first class, it is only necessary to make three pictures, that is six pictures and arrange them in the slides of the instrument in the following order, two of the beginning of the motion, one of the middle position, two of the end position, and one of the middle position. The reason why the extreme positions are placed in pairs together is to cause a dwell or pause at each end of the stroke.

The arrangements were primitive, but no one realized their shortcomings better than did Sellers. Moreover, he recognized the direction the improvements must take before an efficient picture could be produced. With an extraordinary prescience he perceived the need for three vital factors in the reproduction of the motion picture: the flexible ribbon of pictures, a carrier for this ribbon on the viewer, and a mechanism for holding the image intermittently in the beam from the light source.

The idea of the flexible ribbon of pictures is mentioned in the patent application as an alternative arrangement, although for want of celluloid film the means that occurred to Sellers was to attach the pictures "flatways to an endless chain of cloth." This idea was illustrated by a drawing that accompanied the application. As for the

intermittent exposure of the pictures, it is evident from the care he had taken in designing the viewing slits that he was aware of the need for sequential pauses in viewing the images, which would be long enough to permit the eye to register what came into view, interrupted by periods of obscurity brief enough to allow the eye to retain



Heyl's Phasmatrope, 1870.

the impression, yet long enough for the mechanism to bring the succeeding picture into view.

Sellers made no effort to commercialize the Kinematoscope. While he regarded the stage to which he had brought it as nothing more than a form of entertainment (5) there seems no reason to doubt that, at the back of his mind, was the hope that one day it might be developed to demonstrate the operation of machinery. In the patent application

he says specifically that his object was "to exhibit stereoscopic pictures as to make them represent objects in motion, such as the revolving wheels of machinery."

The Kinematoscope lacked two essential features of the motion picture as we know it today. First, was the enlargement of the picture and, second, any attempt at projection so that it could be viewed by more than one person at a time. It might be observed in passing that Edison did not regard these two features as essential, and required a great deal of persuasion before yielding to the pressure of his assistants who perceived their value.

However, both these features were combined in the next stage of development which was also accomplished in Philadelphia by another member of the Institute. Henry Renno Heyl was acquainted with Sellers and it is a tenable conjecture that he was introduced to the Kinematoscope. He must have perceived its limitations and how they might be overcome with the means available. Heyl was a man of extraordinary ingenuity. He is credited with having invented the paper collar when he was still a boy, but he is better known as the patentee of the folding paper-box machine and of a wire stitching machine for books. He had a workshop on the ground floor where the Curtis Building now stands.

Heyl did not patent his machine, but the original is in the Institute museum and he described it in detail at a meeting of members (6). He called his projector the Phasmatrope, and it was used to give the first demonstration of photographs showing people in motion on a screen. This historic event took place on February 5, 1870, at the Academy of Music in Philadelphia. The occasion was the ninth annual entertainment of the Young Men's Society of St. Mark's Evangelical Lutheran Church. Those connected with the entertainment appear to have been aware of the significance of the performance, for the printed program bears the following announcement:

> This is a recent scientific invention, designed to give various objects and figures upon the screen the most graceful and lifelike movements. The effects are similar to those produced in the familiar toy called the Zoetrope, where men are seen walking, running and performing various feats in the most perfect imitation of real life. This instrument is destined to become a most valuable auxiliary to the appliances for illustration, and we have the pleasure of having the first opportunity of presenting its merits to the audience.

The program shown on the screen opened with a picture of Brother Jonathan (as "Uncle Sam" was called in those days) whose lips could be seen to move as he delivered an introductory speech. An expert in lip reading may have had some difficulty in following the words, which were delivered from the wings by Richard Hoffner. This speech is so remarkable for its prophetic expressions that it is worth reproduction in full:

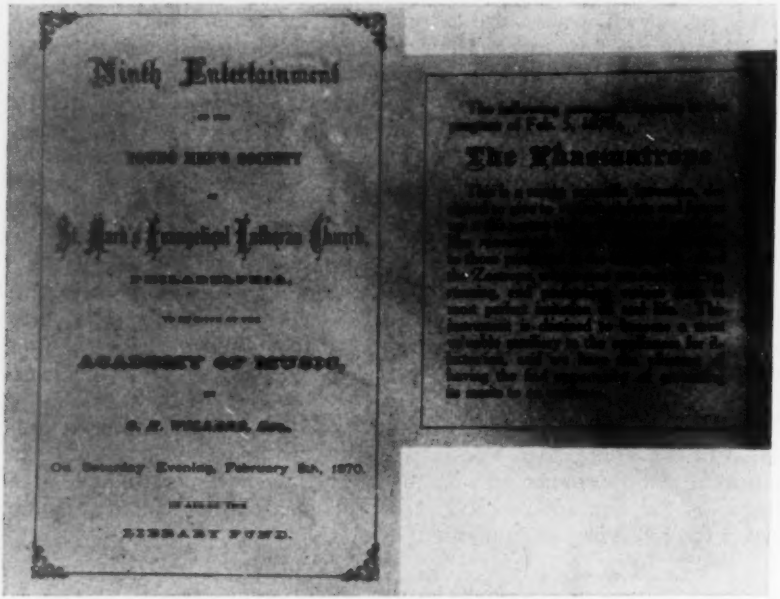
Ladies and Gentlemen:

We are here tonight to see for the first time, photographs of persons shown upon a screen by the aid of a magic lantern, the figures appearing to move in most lifelike ways. How this effect is produced we cannot briefly explain, but you will have the evidence of your own eyes to convince you that this new art will rapidly develop into one of the greatest merit for instruction and enjoyment.

This beginning of greater things is not an imported product, but it was perfected right here in Philadelphia, where it adds one more to the list of first inventions of real merit that stand to the credit of the City of Brotherly Love.

The photographs were made at 1208 Chestnut Street in the studio of Mr. O. H. Willard, which place may now be well named "The Cradle of the Motion Picture."

We welcome you most cordially to witness this unique exhibition (7).



Program of first projected photographic motion pictures.

The program continued with pictures of a waltzing couple (Heyl and his niece) and the antics of "Little All Right," a Japanese tumbler who was making public appearances in the city. The audience of 1500 people who witnessed the performance were treated to another feature which was symbolic of things to come. Not only was Brother Jonathan provided with the power of speech, but the dancing couple waltzed in synchronization with a forty piece orchestra. Heyl anticipated the sound movie!

Finally, since we are dealing with the origins of an industry that is accustomed to trading in very large sums of money, Heyl was able to

say with pride: "We came out of the entertainment with $350 in clean money. Pretty good for one picture show, wasn't it?" (8).

The nucleus of the Phasmatrope was an optical lantern invented by O. B. Brown of Malden, Mass., in 1869 (9), in which colored transparencies (but not photographs) were caused to revolve between an electric arc lamp and a lens. The illusion of motion produced by this lantern was crude and unsatisfactory. Heyl improved upon it by adopting Sellers' principle of having the period of rest and illumination of longer duration than the period of obscuration, although his method of attaining the effect was quite different. Heyl's description of his apparatus was given to readers of the JOURNAL in the following words:

> The piece of mechanism consisted in a skeleton wheel having nine radial divisions, into which could be inserted picture holders, each of which consisted of a card upon which was mounted two of the [transparent] photo positives, in such relative position that, as the wheel was intermittently revolved, each picture would register exactly with the position just left by the preceding one. The intermittent movement of the wheel was controlled by a rachet and prawl mechanism operated by a reciprocating bar moved up or down by hand. It is apparent that the figures could be moved in rapid succession or quite slowly, or the wheel could be stopped at any point to complete a revolution (10).

The revolving wheel was situated in front of a 4-in. condenser. It was revolved with only short periods of rest between exposures, and during the short period of obscuration the light was shut off by a vibrating shutter that was located behind the picture wheel, and operated by the reciprocating bar that moved the wheel. The shutter movement was so timed that it moved first and covered the picture before it moved, and completed its movement after the picture was in place.

The pictures were made by Willard on the popular *carte de visite* size negatives. These were converted into glass transparencies by W. N. Jennings, a well known member of the Institute (11), and reduced to $\frac{3}{4}$ in. in height, approximately the same size as the current film image. The waltzing figures were photographed in the six positions corresponding to the six steps to complete the waltz turn. Each picture was repeated three times to fill the eighteen spaces on the revolving wheel. While the movement of the dancers was timed by the operator to the tempo of the orchestra, the tumbling of the Japanese Little All Right was controlled so that there was a perceptible pause at the end of each somersault to give a greater illustration of reality.

In view of the fact that photography with living models was employed in this exhibition and the pictures were thrown upon a screen, this stands as the first demonstration of the motion picture as we know it today.

Caspar Briggs had acquired the Langenheim business from the surviving brother and, in 1876, he was responsible for introducing a device that was to play a very important part in motion picture projection. This was the Geneva cross for intermittent shutter operation.

Briggs employed this in a curious way to reproduce action upon a screen. On a circular sheet of mica he photographed, by the wet plate process, a skeleton in six different positions. A pulley and string operated the mechanism by which a shutter with an opening revolved continuously. In the wooden frame on which the mechanism and the mica sheet were mounted was a small aperture the size of one of the skeleton figures. When one figure was at rest before the aperture, the opening in the shutter permitted light from the lantern to pass through the mica sheet and the aperture, and so reproduce the image on the screen. As the shutter in revolving covered this figure the mechanism moved the mica sheet to bring the adjacent figure before the aperature. This was continued indefinitely until the operator ceased turning the crank.

The picture of the skeleton (and one of a dancing sailor that followed) was not projected on the screen by itself. Whatever lantern slide was thought suitable to provide a background was first thrown on the screen from another projector and that of the dancing skeleton was super-imposed upon this picture.

As we have intimated, the most significant feature of Briggs' device was the Geneva cross. So far as we can learn, this was its first application to the motion picture. Some idea of its importance may be gleaned from the fact that a claim for the originality of the intermittent shutter action advanced by Edison was denied in the Federal courts on the basis that the principle had been employed from the time of Briggs' dancing skeleton (12).

The scene momentarily turned to California before returning to Philadelphia when the romantic figure of Eadweard Muyridge left the West Coast, where he had succeeded in photographing trotting ponies, to pursue his study of motion at the University of Pennsylvania. It may be extravagant to claim, as many have done, that he was the father of the motion picture. The truth is that he left both the camera and the projector at precisely the same stage in which he found them. Muyridge was more interested in physical motion than he was in the motion picture. Where he stands in the development of the art can be gathered from his own view of the subject as expressed in the paper he read before The Franklin Institute on February 13, 1883 (13):

> Photography, at first regarded as a curiosity of science, was soon recognized as a most important factor in the search for truth, and its more popular use is now entirely subordinated by its value to the astronomer and the anatomist, the pathologist, and other investigators of the complex problems of nature.

Within these limitations placed upon his activities Muyridge justified his work in the analysis of motion. No one would question his attribution of prime value of the motion picture in technology, but had it been narrowed to this field its development would have proceeded along a different path. The greatest advances have been made in synthesis,

which alone built the motion picture into the great industry that provided both the stimulus and the funds that promoted research. However, it can scarcely be denied that Muyridge gave an impulse to the quest for the real motion picture.

In the account of his methods presented before the members of the Institute, Muyridge described how he arranged a battery of cameras in a line parallel with the path of a person's or an animal's motion. Slight threads were stretched across the path so that, when the passage of the moving body tightened the threads before they reached the breaking point, the pressure caused the shutters of the cameras to be tripped in succession. In this way a consecutive group of pictures was made by the battery of cameras. The series of pictures thus obtained provided an analysis of the motion, but it shows the moving body always before the camera with the background scenery moving backwards. No other alternative presented itself to Muyridge. The effect was not of motion as the eye sees it, but rather as the consecutive movements would be seen by a series of eyes at different viewpoints.

For the projection of his pictures Muyridge employed an instrument to which he attached the formidable name of Zoopraxiscope. This was an instrument developed in France by Emile Reynaud that projected pictures from a translucent band on which pictures had been painted. When Heyl saw this instrument he thought he recognized his Phasmatrope but, apparently, Muyridge never saw this latter form of projection. It seems more probable that he borrowed his idea from Reynaud's projector which he could have seen in Paris when he lectured there in 1881. However, he must have improved upon the instrument, for Jenkins says (**14**): "His Zoopraxiscope consisted as to novelty of an immense disc or wheel, one of which is said to have been 13 feet in diameter."

At the World's Columbian Exposition held in Chicago in 1893, a special building called the Zoopraxographical Hall was erected in which Muyridge gave a series of lectures, illustrated with his pictures which were projected on a screen to show the walk of a racoon, the wrinkling of a hog's skin, and numerous other examples of human and animal motion.

When Muyridge was in Paris he was interviewed several times by Meissonier, the famous French artist, whose paintings of military subjects were distinguished for the fidelity of detail. Muyridge's work was of great interest to all artists concerned with the depiction of human and animal locomotion, so that it was not surprising Thomas Eakins, the eminent Philadelphia artist, should have displayed curiosity in his successful analysis of motion. However, Eakins was dissatisfied with the cumbersome methods employed, and resolved upon achieving similar results with a single camera. Some of his negatives were presented to The Franklin Institute Museum by Mr. Charles Bregler,

who assisted the artist in his photographic work. Unfortunately, it is now not possible to say with certainty what methods Eakins used, but it would appear he employed the improved form of Marey's photographic "gun." The inventor, E. J. Marey, was a Parisian who had adopted the "gun" for photographing birds in flight. Later, he improved the instrument until it assumed the form of a conventional camera which obtained records of action intermittently from a single point of view by the revoluton of a handle.

In order to secure continuous motion it was imperative to cut off the light from the photographic plate at regular intervals. This was accomplished by rotating an opaque disc, pierced with small radial slots, which permitted the light to reach the plate intermittently. The interval between two successive images, and the time of the exposure, could be regulated by varying the revolving speed of the shutter. As a rule exposures were made at the rate of ten per second.

A black background was used and the subjects, when not nudes, were clothed in white. This was in great contrast to Muyridge's method, for the sensitized plate surface was opposed by a dead black screen and the lens could remain open without ill-effect upon the photographic plate. When a white clad figure passed across the black background in full sunlight, only this figure was recorded upon the plate. This is only a brief statement of the process, omitting the special arrangements that were necessary to prevent fogging of the plate.

Marey made no effort to project his pictures on to a screen, and some of Eakins' negatives were not intended for projection. However, others have as many as 22 images of a man in motion on an octagonal plate of glass. These could, conceivably, have been used in the stroboscope instrument invented by Briggs, or by the modification of Emile Reynaud's projector used by Muyridge.

Edison had been experimenting in 1887 to produce a machine that would be the visual complement to the sound produced by his phonograph. He wisely strove to discover a release from the inflexible glass plate that had handicaped his predecessors in the field, and had hit upon a celluloid film made by John Carbutt of Wayne Junction. Carbutt made photographic plates and supplies under the trade name of Keystone. He was a member of the Committee on Science and the Arts of the Institute. The film he made was in short lengths that had to be spliced for motion picture work, and it was considerably thicker than the film in use today. However, Edison cut the Carbutt film to the size that is still standard. He did not become acquainted with the Eastman film until 1889.

Edison's first motion picture was a peep show in which a film strip about 50 feet long was run over a series of spools. This did not present any great problem, but when other inventors wished to get away from the peep show and to project their pictures on a screen they were also

faced with the problem of providing a picture of longer duration. Now that the pliable Eastman film was available it was a simple matter to extend the length of the film to 1000 ft. But such a length of film could not be drawn through either the camera or projector without jerking the film and causing it to break.

Activity was now great and competition severe among the various inventors who were striving to perfect both the motion picture camera and the projector. The situation became so complicated that it is exceedingly difficult to disentangle the facts from the mass of contradictory evidence that was furnished in the subsequent law suits over priority, but it would appear that a highly important solution to the jerking and breaking of film was presented independently by two rival groups. The solution was provided by the addition of an extra feed sprocket that formed a loop of slack film from which the intermittent motion was taken without jerking the film.

On December 18, 1895, Charles F. Jenkins addressed the members of the Institute on the construction of the Phantoscope he had invented. He also demonstrated the operation of the machine at this meeting (15). The machine had previously been demonstrated without arousing any great enthusiasm at the Cotton States Exposition held in Atlanta in the previous September. As a result of the Institute exhibition, the development of the Phantoscope was investigated by the Committee on Science and the Arts, and it was decided to award Jenkins the Elliott Cresson Medal. Apart altogether from the rival claims to ownership of the patents and the priority advanced in a bitter controversy that raged for years in the law courts, the award of the medal for the Phantoscope was thoroughly justified, for impartial judgment leads to the conclusion that this was the first successful device for putting motion pictures on the screen in America.

The Phantoscope embodied two essential developments that had been bugbears to previous inventors. The first was the loop of slack film to which allusion has been made, and the other was the provision of a longer period of rest and illumination for the picture, and a quick movement from one picture to its successor. When the legal storm broke in 1898 with suits and countersuits, the records of the subcommittee (Messrs. Heyl, Carbutt, and Hoadley) that had investigated the instrument were found to be valuable material for establishing claims to priority to the invention of some significant parts of the motion picture projector.

When the Phantoscope went out to meet competition it encountered an opposition that was characteristic of the lawless and ruthless methods that were common at the time. The head of one entertainment company favoring a rival machine in Chicago wrote: "The Phantoscope, which appeared a couple of times . . . in this city, made a big frost, and is dead here for some time to come. I had a great deal to do with

the failure of the machine, as one of our electricians was engaged to run it—so you understand the rest of it."

One man had faith in the Phantoscope. This was Sigmund Lubin, a spectacle maker who had only recently arrived in the United States when a friend introduced him to the newly developed motion picture. He was practicing as an optician at 23 South 8th Street, Philadelphia. He acquired from Jenkins a complete outfit and plunged into the business. Men of wider experience and greater capital had been active in promoting the Fitzsimmons-Corbett prize fight for the world championship in order that they might photograph it. When the picture was eventually produced on the screen it became obvious that a handsome profit would be made from it and others of a similar nature.

Employing two husky freight handlers from the Pennsylvania Railroad terminal, Lubin caused the combat to be re-enacted, with a prompter reading a newspaper blow by blow account of the championship fight. This picture was released for exhibition under the title of "The Great Corbett-Fitzsimmons Fight (in counter part)." This was true motion picture art—the re-creation of an event—with the vengeance! The owners of the original fight picture had no legal recourse.

An advertisement Lubin published hints at the precarious nature of the exhibitor's enterprise at the time and the manner in which he was striving to make it less hazardous (16). For an outlay of $99.00 a prospective exhibitor could obtain a projector, electric lamp (with a calcium light if the community was without electric current), a Victor Talking Machine and two records of appropriate music.

Lubin had a studio at 526 Market Street, Philadelphia. Here he made what pictures, or parts of them, could be made indoors. For shots "on location," he acquired a property at Betzwood, near Norristown, where a huge pile of sawdust served as mountain scenery. He achieved numerous successes during twenty years of production, but he lamented that his most profitable picture had been made in 1897, and was entitled "Horse eating Hay."

Although his principal influence was felt in the production and distribution of motion pictures, he did place a projector on the market. This was called the Cinograph, but it does not appear to have introduced any new technical element, and has the appearance of being a modification of Jenkins' early machine.

Photography had now reached a stage of high perfection. But, as the pictures were all in black and white, there was a natural desire to produce pictures in color. One of the Institute members, Frederick E. Ives, had already distinguished himself as an inventor in photography and color engraving. He applied himself to the problem of introducing color to the motion picture, and soon reported some degree of success. Ives was not trained in optics, or any other science, which

makes his accomplishments doubly remarkable. He had been compelled to leave school at the age of eleven and had gone to work as a printer's devil. By combining his knowledge of printing processes and photography he established a reputation in the field of photo-engraving. Through various causes for which he was in no way to blame, he failed to reap the rich rewards that others gained from his inventions.

He first attracted attention of Institute members when he fitted their projection lantern with his "ether saturator." At first, this used the vapor of sulfuric ether as a substitute for hydrogen or coal gas in producing the intense flame of the lime light. This Franklin Institute installation was the first of its kind, but it was later frequently adopted before electric current was available.

Altogether Ives took out over seventy patents, several of which were important in color motion pictures. These included the invention and designing of special cameras and physical equipment (1916–19); light splitting devices for cine-color cameras, permitting the use of lenses of larger than normal aperture, thus doubling their efficiency (1917–21); two color motion picture production on single-coated ordinary positive film (1914–18); two color cine-films made by cementing differently colored strips together and bipack films (1917–19); trichromatic cine-print in a single colloid layer (1916); and several others (17).

Because of its efforts and interests in the promotion of motion pictures it is appropriate that The Franklin Institute should have some permanent feature that will recapture the old spirit of pioneering in the field. This has taken the form of the Nickelodeon installed in the Museum. The installation is a replica of an old motion picture theatre at the period when these structures were being erected to replace the tents and improvised halls for exhibition. An atmosphere of the early days of the twentieth century has been retained by the employment of authentic material wherever that could be obtained. This evocation of the past was made possible through the generosity and inspiration of Mr. William Goldman, a pioneer exhibitor now prominent in both exhibiting and producing the best in motion pictures.

Films associated with the early years of the industry are shown in the Nickelodeon, but the joy with which these are received by the youth of the present generation is conclusive proof of the enduring nature of this form of entertainment. With the coming of maturity to the industry it has passed the stage of concentrating upon the art of being amusing and has become a potent agent in education. Films of an educational nature are also shown in the Nickelodeon. Prominent among these are films that show industrial processes and new techniques, thus maintaining the Institute's function of fostering an interest in industrial enterprise.

REFERENCES

(1) ATHANASIUS KIRCHER, "Ars Magna Lucis et Umbrae in Mundo," 1646.
(2) JOUR. FRANKLIN INST., Vol. 28, p. 303 (1839).
(3) U. S. Patent No. 7784, November 19, 1850.
(4) U. S. Patent No. 31,357, February 5, 1861.
(5) HOMER CROY, "How Motion Pictures are Made," New York, Harper, 1918, p. 8.
(6) At a stated meeting held on March 16, 1870.
(7) Heyl Papers in the Library of the Institute.
(8) Undated newspaper clipping captioned "Current Topics of the Town" in Heyl papers.
(9) U. S. Patent No. 93,594.
(10) Letter to the editor, JOUR. FRANKLIN INST., Vol. 145, p. 310 (1898).
(11) W. N. JENNINGS, "Photography and The Franklin Institute," JOUR. FRANKLIN INST., Vol. 234, p. 31 (1942).
(12) *Pennsylvania Arts and Sciences*, Vol. 4, No. 1, p. 65 (1939).
(13) JOUR. FRANKLIN INST., Vol. 115, p. 260 (1883).
(14) C. F. JENKINS, "Animated Pictures," Washington, Jenkins, 1898, p. 10.
(15) JOUR. FRANKLIN INST., Vol. 141, p. 80 (1896).
(16) *Billboard*, October 15, 1904.
(17) *J. Appl. Phys.*, Vol. 9, p. 236 (1938).

PLASMA FLUCTUATIONS IN CROSSED ELECTRIC AND MAGNETIC FIELDS*

BY

H. W. BATTEN,[1] H. L. SMITH[1] AND H. C. EARLY[1]

ABSTRACT

An experimental study has been made of the high-amplitude electrical fluctuations associated with a gas discharge in a strong magnetic field. Hydrogen, helium, argon, and nitrogen gas were used at pressures from 0.3 to 100 microns. The power spectrum on plasma probes was investigated for various values of magnetic field, gas pressure, and power input to the discharge. For the range of frequencies studied (0.5 to 4000 megacycles per second), the spectrum shows a continuous high level that increases in amplitude with decreasing pressures at all frequencies and increases with increasing magnetic field at low frequencies. A sharp dip in the spectrum was observed near the ion cyclotron frequency for discharges in hydrogen and helium. The velocity and direction of propagation for the low frequency fluctuations were determined by cross-correlating the potential variations on two neighboring probes. These fluctuations appear to propagate in the direction of the electron drift and at a velocity somewhat less than the Lorentz drift velocity.

INTRODUCTION

A low-pressure, electrical discharge transverse to a strong magnetic field is characterized by large-amplitude, plasma fluctuations (1).[2] These spontaneous electrical fluctuations are hundreds of volts in amplitude, and play an important role in the scattering, diffusion, and ionizing processes of the gas (2). Without the magnetic field, the spectrum of the fluctuations consists of discrete frequencies (3), while the presence of the magnetic field suppresses these isolated frequencies and produces broad frequency ranges of high-intensity noise.

The present paper outlines an experimental study of the spontaneous fluctuations associated with a glow discharge in a strong transverse magnetic field. The objective is to answer the following questions:

1. How is the power in the fluctuations distributed in frequency? How does this distribution depend on the pressure, magnetic field, and type of gas?
2. Do these fluctuations propagate in the medium? If so, in what direction do they propagate, and how fast?
3. Do these fluctuations amplify or attenuate as they propagate?

* This research was sponsored by the Office of Ordnance Research, U. S. Army.

[1] Engineering Research Institute of the University of Michigan, Ann Arbor, Mich.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

EXPERIMENTAL APPARATUS

All the experiments used the cylindrical electrode geometry shown in Fig. 1. The anode was 8 in. in diameter; part of this anode was made of copper screen so the discharge could be seen during operation. The cathode consists of the two disks in the center of the cylinder, the cathode action being similar to that in a Phillips Ionization Gage.

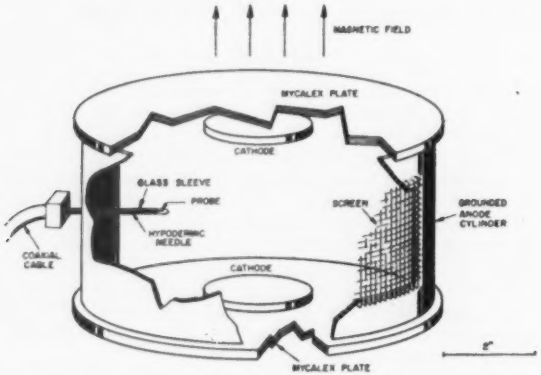


FIG. 1. Electrode structure used in the experiments, showing probe in place.

The entire assembly of Fig. 1 was located inside a large vacuum chamber. A glass window on one side of the chamber provided good visibility of the discharge. To minimize contamination of the gas, a fast vacuum pump (100 liters per second) was used, and gas was bled into the chamber at a rate sufficient to maintain the desired equilibrium pressure. The undesirable effects due to heating and outgassing of the dielectric plates were avoided by operating the discharge for only short intervals.

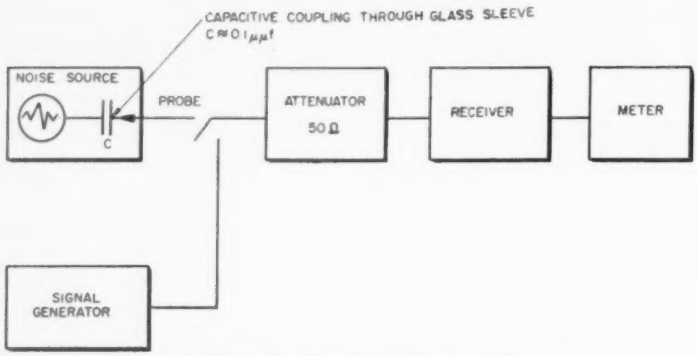


FIG. 2. Block diagram of instrumentation circuit.

All the data were taken near the close of a three to five second operating interval.

Figure 2 is a block diagram illustrating the method used for obtaining the spectral data. The plasma probe consisted of a short tip of fine wire projecting from the end of a hypodermic needle as illustrated in Fig. 1. The fine wire passing through the hollow needle formed a 50-ohm coaxial line. This probe assembly was connected to a terminated length of 50-ohm R.G. cable so the load impedance seen by the probe was the same at all frequencies. The projecting wire tip which formed the active part of the probe was covered with an insulating glass sleeve, and all the voltage induced in the probe was due to capacitive coupling.[3] The 50-ohm cable from the probe was connected to a superheterodyne receiver through an isolation attenuator. The output of this receiver was metered so that the noise input in the passband of the receiver could readily be determined by using a signal generator as shown in Fig. 2.

CHARACTERISTICS OF A "REVOLVING PLASMA" DISCHARGE (4,5)

The presence of the axial magnetic field gives the electrode geometry used in these experiments a resemblance to a smooth-bore magnetron. The ions and electrons have a large circumferential component of drift velocity and the resulting momentum exchange with neutral gas molecules causes all of the gas in the region to revolve at high velocity. This high velocity "wind" can be observed by mounting a small flag of mica or glass cloth which will stand out horizontally in the air stream. Visually, the discharge in nitrogen is pale blue and quite transparent, the region between the cathode discs being more densely luminous than the rest of the plasma.

The discharge was usually operated at a current of 0.5 amp. With a gas pressure of 0.01 mm. of Hg, and a magnetic field of 3500 gauss, the average voltage across the electrodes was approximately 1500 volts. The power supply voltage was 8000 volts, most of the voltage drop occurring in a non-inductive resistance in series with the cathode lead. Thus, the discharge operated at essentially constant current conditions.

THE POWER SPECTRUM OF THE DISCHARGE

A great many parameters affect the experimental study of the power spectrum. They include the type of gas, gas pressure, magnetic field strength, discharge current, type of probe, position and orientation of the probe, and many others. A survey of the influence of these factors has been made, and certain features are especially interesting.

Figure 3 shows the power spectrum of the voltage fluctuation on a probe in a hydrogen discharge. The striking characteristic of this curve is the sharp dip at the ion cyclotron frequency and the rise in the curve above and below that frequency. It is important to note that

[3] The merits and shortcomings of various types of probes are discussed in the Appendix.

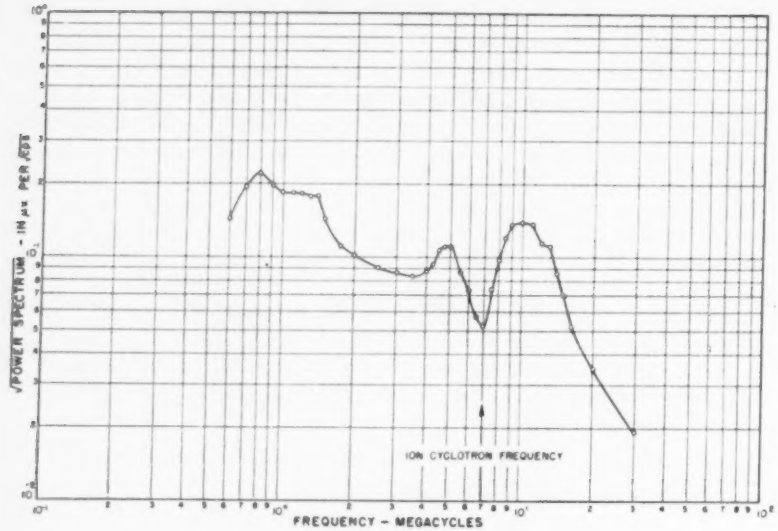


FIG. 3. Hydrogen discharge in a magnetic field.
B = 4550 gauss
I = 0.5 amp.
P = 4.5 microns

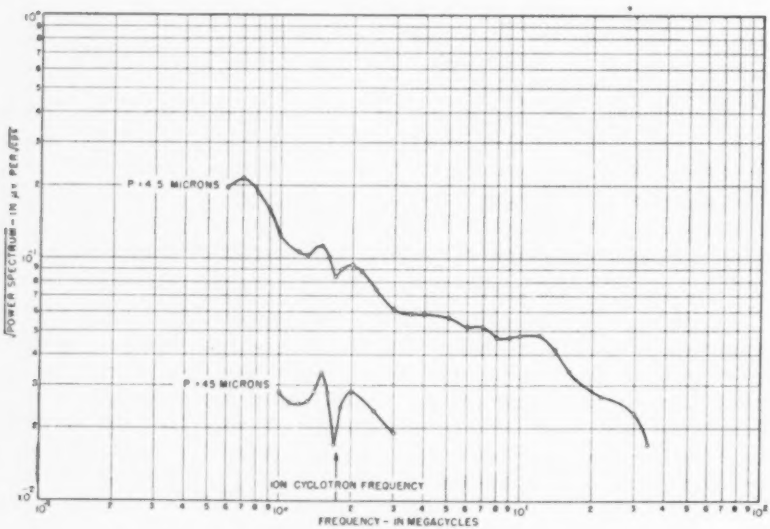


FIG. 4. Helium discharge in a magnetic field.
B = 4550 gauss
I = 0.5 amp.

the cyclotron frequency is computed assuming an ionized atom; if the ionized molecules are present in the gas, their effect is certainly much less pronounced in the spectrum. Two other features in Fig. 3 are of interest. (1) Near 800 kilocycles per second there appears to be a broad resonance. It is likely that this resonance is to be identified with ions oscillating in a potential minimum as discussed by Ballantine, and later Cobine (6). (2) The power spectrum seems to decrease markedly near 15 megacycles per second.

The cyclotron dip, similar to that of Fig. 3, is shown in Fig. 4 where the power spectrum for a helium discharge is given. It is of interest to note that the dip is less pronounced for helium than for hydrogen.

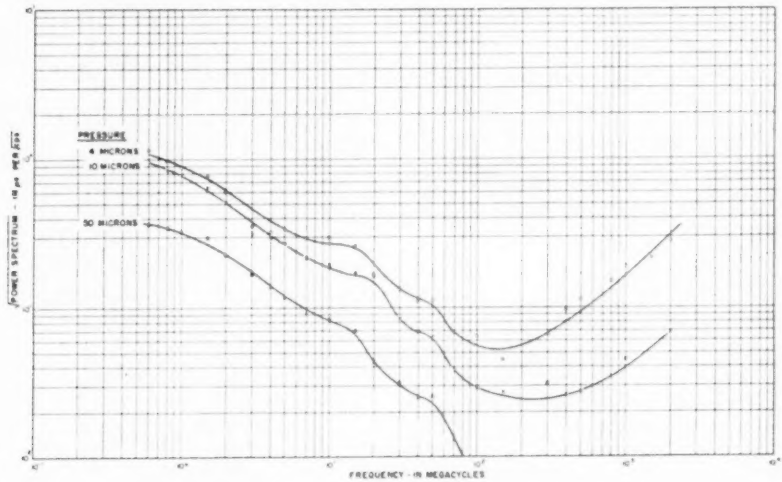


FIG. 5. Spectral distribution of nitrogen discharge in a transverse magnetic field.
B = 4550 gauss
I = 0.5 amp.

Perhaps this is not surprising, for the higher atomic weight implies an increase in the ion collision frequency relative to the cyclotron frequency, and such an increase would likely dampen any pronounced effect at the cyclotron frequency. Probably this is the reason Cobine in his extensive studies did not report any peculiar behavior of the spectrum at the ion cyclotron frequency (3). Most of his work was with heavier gases than hydrogen and helium; he also used higher pressures and lower magnetic fields than considered here and this would increase the damping at the cyclotron frequency.

Figure 5 shows data taken for nitrogen over a broad frequency range. The ion cyclotron frequency for nitrogen is less than half a megacycle per second and the characteristic dip does not appear in the figure. The absolute calibration on the ordinate is not too significant

since it depends on the probe size, but some idea of what the numerical value of the ordinate implies is given by noting that the thermal noise from a matched resistance at room temperature would plot as a horizontal line in Fig. 5 with an intercept at 4.5×10^{-4}. This value is far less than the spectral level represented in the figure. The curves of Fig. 5 show a very broad spectrum, high in intensity compared with thermal noise. Careful investigation showed that there were no

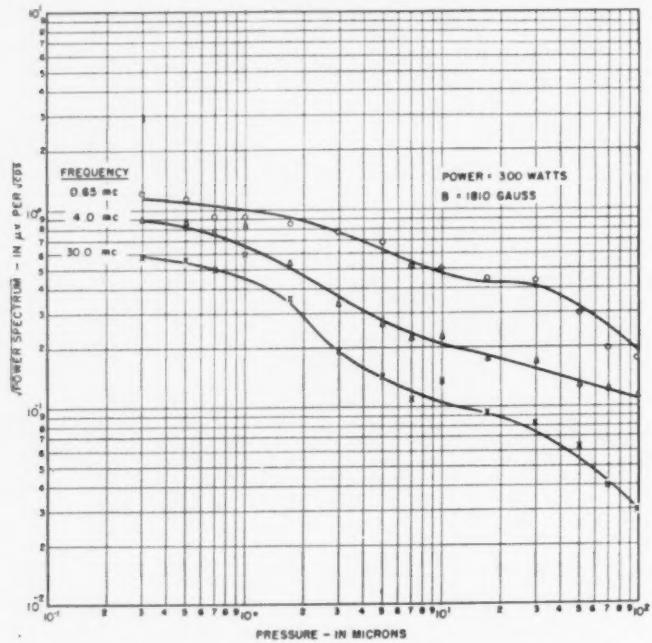


FIG. 6. Spectral distribution for nitrogen as a function of pressure with constant power input.

isolated resonances in this broad frequency range. Varying the magnetic field strength throughout the 1000- to 5000-gauss range did not affect the character of the spectrum. For values of magnetic field less than a few hundred gauss the diffusivity and other visually observable characteristics of the discharge changed considerably. The cathode behavior became erratic, and reliable data would have been difficult to obtain.

The influence of pressure is shown prominently in Fig. 5. An increase in pressure decreases the power spectrum at all frequencies. This result was checked over a wide range of pressures for particular frequencies. The result is shown in Fig. 6. The lowest pressures of

these curves represent the least values of pressures at which the discharge could be sustained for the fixed power input. These curves

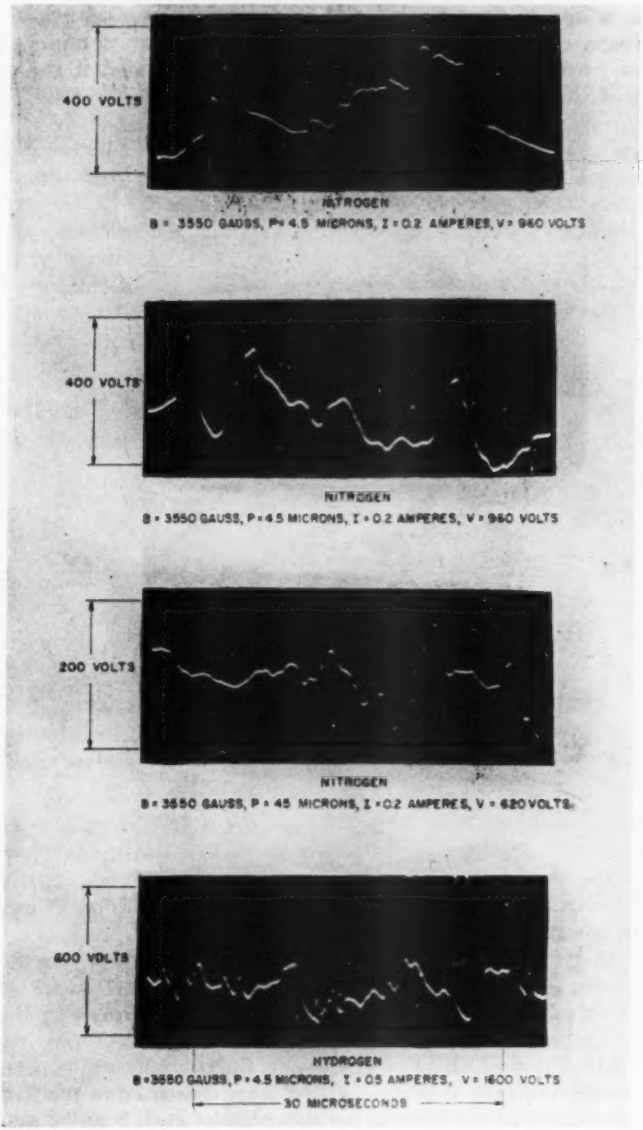

400 VOLTS
NITROGEN
B = 3550 GAUSS, P = 4.5 MICRONS, I = 0.2 AMPERES, V = 960 VOLTS
400 VOLTS
NITROGEN
B = 3550 GAUSS, P = 4.5 MICRONS, I = 0.2 AMPERES, V = 960 VOLTS
200 VOLTS
NITROGEN
B = 3550 GAUSS, P = 45 MICRONS, I = 0.2 AMPERES, V = 620 VOLTS
400 VOLTS
HYDROGEN
B = 3550 GAUSS, P = 4.5 MICRONS, I = 0.5 AMPERES, V = 1600 VOLTS
30 MICROSECONDS

FIG. 7. Potential fluctuations on a probe in a gas discharge.

indicate that over a wide pressure range a decrease in pressure causes an increase in the spectral energy.

The data were taken at a constant power input to emphasize that the percentage of power converted to noise increases with a decrease in pressure. Thus, the device as a noise generator is more efficient at lower pressures. Similar curves would be obtained if the current instead of the power were kept constant, except that the decrease in noise at higher pressures would be exaggerated because of the reduction of power input at the higher values of pressure. This higher efficiency of noise generation with reduction of pressure has been found in all the studies of hydrogen, helium, argon, and nitrogen. Different probes, magnetic fields, or other parameter changes do not seem to alter this result. Perhaps such a general conclusion is to be anticipated because the damping of the fluctuations is due to the rate of collisions of the charged particles, and a reduction in pressure reduces the collision rate.

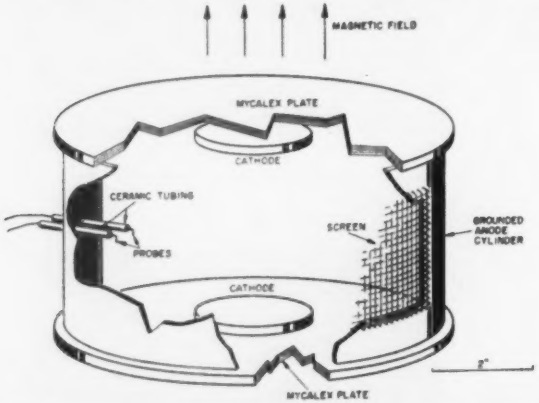


FIG. 8. Electrode structure and probe arrangement for the study of propagation velocity.

PROPAGATION VELOCITY AT LOW FREQUENCY

The previous section discussed the distribution of the fluctuating energy with frequency. This section is concerned with the time variations of the plasma fluctuations. By comparing the time variations on two different probes, the speed and direction of propagation of the fluctuations can be determined.

For the low frequency studies, bare wire probes were used. Electrically the probes were connected through a 300,000-ohm load resistance to a positive potential. By biasing the probes in this way, their potentials remained slightly above the plasma potential and apparently followed the low frequency fluctuations quite accurately. The characteristics of this type of probe are discussed in the Appendix.

Photographs of the fluctuating potential of such a probe are shown

in Fig. 7. The high intensity and random nature of this disturbance is particularly interesting. If a second probe is placed in the discharge 1 in. from the first and at the same distance from the anode, as indicated in Fig. 8, the fluctuations on the two probes typically have the appearance shown in Fig. 9. The corresponding potentials on the two probes

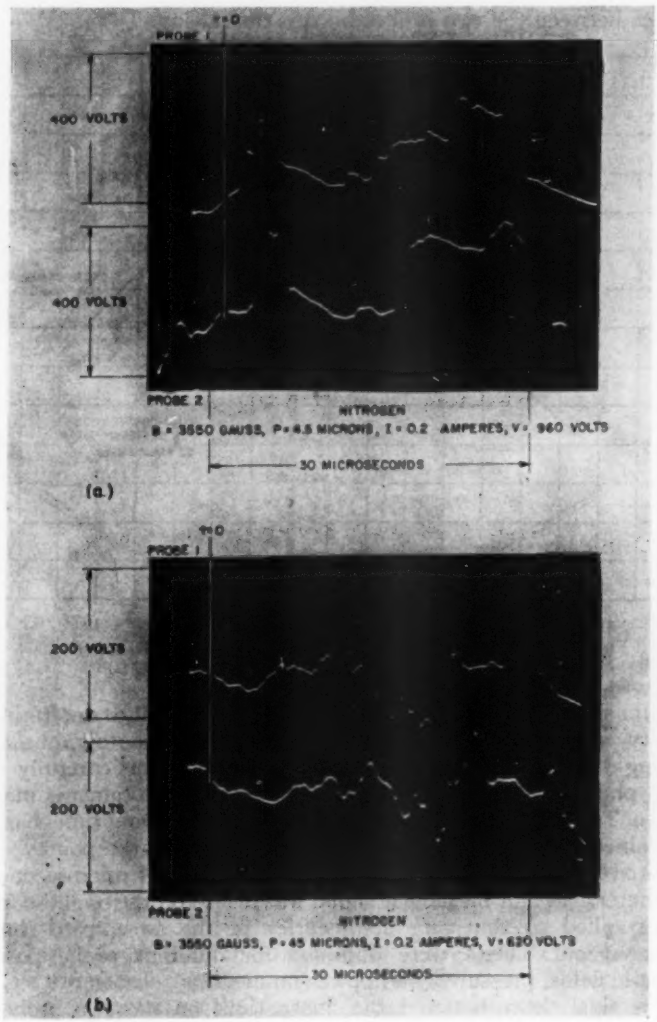


FIG. 9. Potential fluctuations on two neighboring probes.

appear remarkably alike, with two important exceptions: (1) the fine structure is different, (2) the voltage on probe 2 is delayed in time with respect to the voltage on probe 1. This delay is related to the time it takes the fluctuation to travel from one probe to the other. If the line from one probe to the other is the direction of propagation, then the velocity can evidently be determined merely by dividing the distance between the two probes by this time delay.

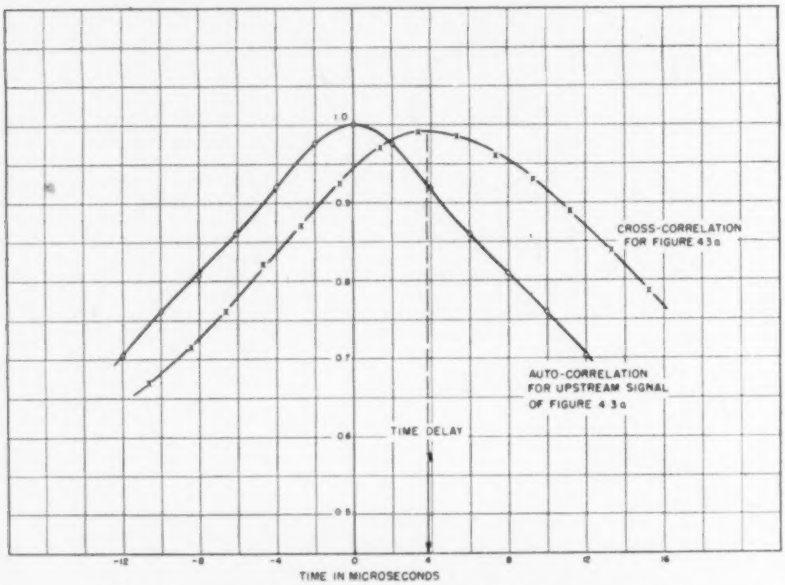


FIG. 10. Representative curves of auto-correlation and cross-correlation used to determine the correlation velocity.

Data were obtained photographically as in Fig. 9 to determine this velocity, except that a reticule appears on the photographs of the working data and the average level of the voltage was carefully noted. These photographs were taken with Polaroid Land cameras mounted on two Tektronix 513D oscilloscopes. The common time base was determined by intensity modulating both beams at the point $t = 0$ as indicated in Fig. 9. The sweep-rates were set at 4 microseconds per centimeter. A half-megacycle signal was placed on the oscilloscope and photographed so that any nonlinearity in the sweep-rate could be calibrated out. Data were obtained for different probe positions, magnetic fields, pressures, and power inputs.

The time delay between the fluctuations on the two probes was determined by cross-correlating the two potentials. That is, calling the potential on probe 1, $\phi_1(t)$, and that on probe 2, $\phi_2(t)$, the value of

τ for which the correlation function $\overline{\phi_2(t + \tau)\, \phi_1(t)}$ reached its maximum was taken as the delay. The bar over this product means the average in time, (the average is extended over all time where the potentials are defined by the photographs). Figure 10 shows the cross-correlation

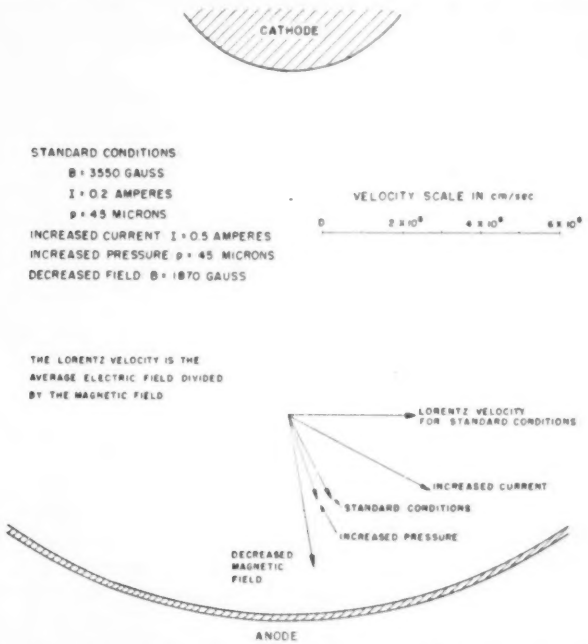


FIG. 11. Vectors showing the direction and amplitude of the propagation velocity.

for the pair of curves given in Fig. 9*a*, and also the auto-correlation for the potential on probe 1 of the same figure. In this case, the correlation functions have been normalized to unity in the usual way, that is,

$$\text{cross-correlation} = \frac{\overline{\phi_2(t + \tau)\, \phi_1(t)}}{\sqrt{\overline{\phi_1^2(t)}\, \overline{\phi_2^2(t)}}}$$

$$\text{auto-correlation} = \frac{\overline{\phi_1(t + \tau)\, \phi_1(t)}}{\overline{\phi_1^2(t)}}.$$

The fact that the cross-correlation of Fig. 10 reaches a value of 0.99 indicated that apart from the delay of 3.8 microseconds the potentials of Fig. 9*a* are nearly the same.

Figure 11 summarizes the important results of the velocity measurements. The figure shows the direction and magnitude of the velocity of propagation in nitrogen gas with various conditions of operation.

It is seen that this velocity is the same order of magnitude as the Lorentz drift velocity and is directed in the same quadrant as the electron drift velocity. This suggests that the fluctuations propagate with approximately the average electron velocity. If this is true it supports one hypothesis which requires that the fluctuations amplify as they propagate, in a manner analogous to that found in a traveling-wave tube.

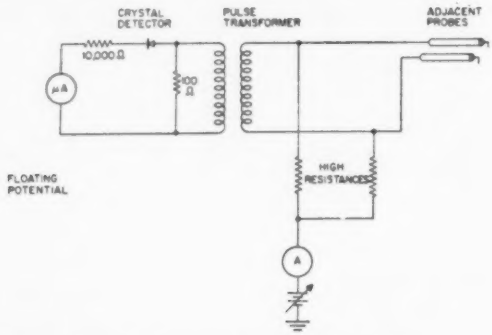


Fig. 12. Circuit for measuring amplification with propagation.

THE AMPLIFICATION WITH PROPAGATION

In order to test the assumption that the fluctuations can be identified with waves that amplify as they propagate, a special type of double probe experiment was devised. With the probes of the previous section, the fluctuating potentials were measured with respect to the grounded anode and hence included the effects of voltage gradients in the vicinity of the anode as well as gradients in the immediate vicinity of the probe. To measure only the local intensity of a disturbance, it was desirable to design a probe system that would respond only to potential gradients in a localized region. This was accomplished by using two adjacent probes connected to a small pulse transformer which served to isolate the probes from ground and also acted as a differential input transformer. Figure 12 is a schematic diagram of the circuit. The two probes were connected to opposite ends of the transformer primary, and only the voltage between the two probes produced a voltage in the secondary. Biasing currents for the two probes were supplied through a resistance which was high enough to minimize any shunt loading. This biasing current was maintained constant as the probes were moved to different points in the discharge.

Capacitance between the probes and ground (through the transformer) was reduced by "floating" the transformer core, crystal detector, resistance, and the microammeter with respect to ground. The circuit was tested with a signal generator, and it was shown that the output depended only on the differential input at the probes.

The data of this section are shown in Fig. 13, where the voltage difference between the probes is plotted as a function of the distance from the probes to the cathode. The operating pressure, magnetic field and current are the same as the standard conditions given in Fig. 11. The curve of Fig. 13 is hardly conclusive evidence for gain, but in the region between cathode and anode there is an apparent gain of about 5 db. per inch. This supports the hypothesis that the noise fluctuations amplify as they propagate.

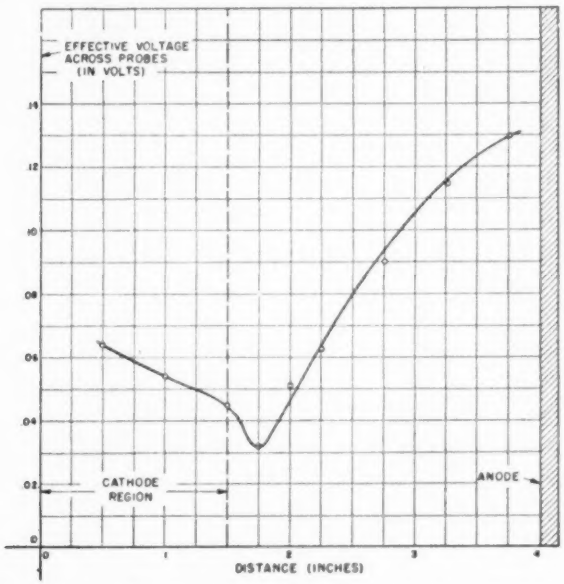


FIG. 13. Curve showing the amplitude of fluctuations between probes as a function of the position of the probes.

CONCLUSION

High-amplitude, plasma fluctuations characterize an electrical discharge in a transverse magnetic field. These fluctuations are hundreds of volts in magnitude and extend from d.c. to the microwave frequencies. The spectrum is principally due to electron disturbances, but ions make a significant contribution near the ion cyclotron frequency, especially for the light gases. The fluctuations appear to propagate in the direction of the electron drift and approximately at the electron drift velocity. There is evidence to suggest that these fluctuations amplify as they propagate.

Acknowledgment—The authors wish to acknowledge the assistance of Professors W. G. Dow and G. Hok during many phases of this study.

REFERENCES

(1) H. W. BATTEN AND H. C. EARLY, "Plasma Fluctuations in Crossed Electric and Magnetic Fields," Technical Report No. 2, Engineering Research Institute, University of Michigan, Office of Ordnance Research Contract No. DA-20-018-ORD-11913, May 1954.

(2) D. GABOR, "Plasma Oscillations," *Brit. Jour. of App. Phy.*, Vol. 22, p. 209 (1951).

(3) J. D. COBINE AND C. J. GALLAGHER, "Noise and Oscillations in Hot Cathode Arcs," JOUR. FRANKLIN INST., Vol. 243, p. 41 (1947); and "Effects of a Magnetic Field on Oscillations and Noise in Hot-Cathode Arcs," *J. Appl. Phys.*, Vol. 18, p. 110 (1947).

(4) H. C. EARLY AND W. G. DOW, "Supersonic Wind at Low Pressures Produced by Arc in Magnetic Field," *Phys. Rev.*, Vol. 79, p. 186 (1950).

(5) H. C. EARLY, H. L. SMITH AND D. C. LU, "Electrical Wind Phenomena," Summary Report No. 1, Engineering Research Institute, University of Michigan, Office of Ordnance Research Contract No. DA-20-018-ORD-11913, November 1952.

(6) S. BALLANTINE, "Fluctuation Noise Due to Collision Ionization in Electronic Amplifier Tubes," *Physics*, Vol. 4, p. 294 (1933); and Cobine and Gallagher, *op. cit.*

(7) W. D. MCBEE AND W. G. DOW, "The Influence of a Transverse Magnetic Field on an Unconfined Glow Discharge," *Trans. A. I. E. E.*, Vol. 72, Pt. I, pp. 229–238 (1953).

APPENDIX

Probe Design

An ideal plasma probe should sample the fluctuating electrical potential at a given point in the plasma without disturbing the phenomena being sampled. To achieve this, the probe should be as small as possible, and the load impedance due to the associated circuitry should be high enough so that the probe is free to "ride along" with the potential fluctuations. However, in any realizable probe design, the effects of stray capacitance and load impedance become quite serious. The two designs which were used in this investigation fall short of what might have been desired and represent compromises of the ideal probe requirements.

The probe shown in Fig. 1 used a hypodermic needle covered with a glass sleeve. The wire passing through the needle formed a coaxial line having the same impedance as the coaxial cable to which it was connected. This arrangement had the advantage that the load impedance of the terminated coaxial line was constant at all frequencies. Since the cable impedance of 50 ohms was objectionably low, the probe was covered with an insulating glass sleeve which reduced the tendency of the probe to disturb the "waves" propagating through the plasma. Of course, this capacitance type of coupling through the glass was frequency sensitive, and caused a decrease in the response at the low frequency end of the power spectrum.

The "bare" wire probe shown in Fig. 8 was used for the propagation studies at low frequencies where the signal from the glass sleeve probe was too low. Instead of using a terminated coaxial line, the probe was connected directly to the high impedance input of an oscilloscope and all stray capacitance was reduced to a minimum. The total capacitance to ground including the oscilloscope input was not over 25 $\mu\mu fd$.

An "exposed" wire probe of this type in a gas discharge plasma tends to act as a diode rectifier since the electron current associated with a positive potential is many times larger than the ion current for a negative potential. Hence, unless suitable precautions are taken, the probe behaves as a diode peak reading voltmeter, accepting electrons only on the negative peaks of plasma voltage swing and maintaining an average d-c. potential which is perhaps 50 to 100 volts more negative than the average potential of the surrounding plasma (7). Since the voltage on such a probe would be a poor reproduction of the plasma fluctuations, it was found desirable to connect the probe through a high load resistance to a positive bias voltage of several hundred volts so that a continuous electron current was drawn from the plasma. When biased in this manner, the probe tends to maintain a potential slightly positive with respect to the instantaneous plasma potential and apparently follows the low frequency fluctuations rather accurately.

ANALYSIS OF MAGNETIC CIRCUITS WITH GIVEN D-C. EXCITATION

BY

EVERETT H. MITCHELL[1]

ABSTRACT

The conventional method for determining the intensity of flux in magnetic circuits with given excitation is well known to be of the trial and error type of solution. Since this procedure entails considerable labor and is, in general, lacking in neatness and formality, it would seem desirable to develop a simple direct method of solution. The solution developed here is unique in the sense that it reduces the problem to the utilization of a single curve which is dependent upon the material alone and is strictly independent of the geometry of the core itself.

This means that for a given material, the correct value of the flux may be obtained by employing the same curve for all magnetic circuits, regardless of the length and area of the core or the length and area of the air gap (or gaps). Since direct methods of the past require that a separate distinct curve be plotted for a given core, the method derived here presents a definite improvement over previous practices.

NOTATION

NI = ampere-turns,
L_a = length of air gap, inches,
A_a = area of air gap, square inches,
L_c = total mean length of core, inches,
A_c = area of core, square inches,
B = flux density, kilolines per square inch,
ϕ = flux, kilolines, and
K = reciprocal of permeability of the core material under non-saturated conditions.

I. INTRODUCTION

In the analysis of magnetic circuits with d-c. excitation, the problem of determining the flux for a given excitation is well known to be a trial and error procedure. Although there is no set process, this type of solution is usually effected by assuming that all of the ampere-turns are used to create the air-gap flux. The next step in this type of solution consists of computing the flux resulting from this assumption. This value is then reduced by a small amount and the corresponding ampere-turns for the core and air are added. This answer is then compared to the given total number of ampere-turns to give an indication of error. This process is repeated until a satisfactory value is obtained.

It is evident that if a direct method of solution is derived, several difficulties will be eliminated. The purpose of this paper is, then, to

[1] Medium Steam Turbine Generator and Gear Department, General Electric Company, Lynn, Mass.

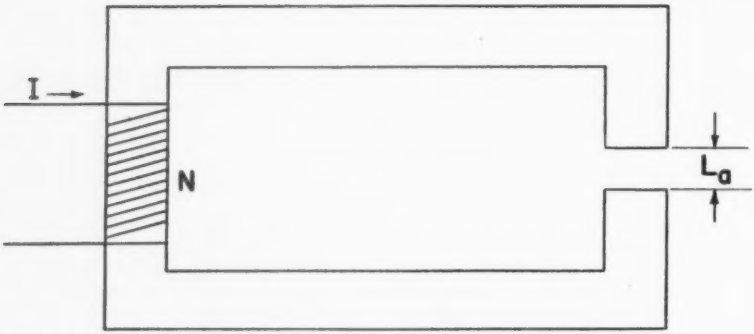


FIG. 1. Simple magnetic circuit with iron core and air gap.

derive such a method and demonstrate how it may effectively be utilized in the analysis of magnetic circuits.

The investigation is confined to simple magnetic circuits of uniform cross-sectional core areas (see Fig. 1). Since most magnetic circuits of a complex nature may be broken down into a number of simple circuits, there is no serious loss of generality resulting from this restriction. The cross-sectional area of the air gap is assumed to be different from the cross-sectional area of the core, to allow for fringing about the air gap. The effect of saturation is included by assuming that the magnetizing force is equal to a constant times B plus a constant multiplied by B raised to a higher power. Comparison shows that a function of this nature very accurately represents the behavior of a

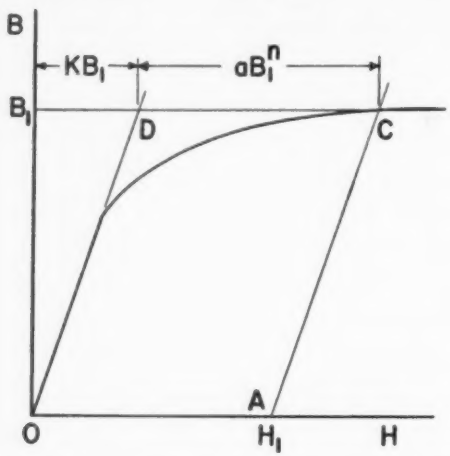


FIG. 2. Graphical determination of B_1 from normal magnetization curve.

magnetic circuit in the normal working region of the normal magnetization curve.

II. RESULTS

Given, in the circuit in Fig. 1, NI, A_c, L_c, A_a, L_a, and the normal magnetization curve of the core material. To find ϕ first evaluate,

$$H_1 = \frac{NI}{L_c}. \tag{1}$$

Next, obtain a corresponding quantity, B_1, as shown in Fig. 2. The line AC is drawn parallel to the initial straight line portion of the magnetization curve. The intersection of this line and the curve determines the appropriate value of B_1.

The next step in this solution consists of evaluating

$$r = \frac{H_1}{\left(\dfrac{313 L_a A_c}{A_a L_c} + K\right) B_1}, \tag{2}$$

where K is the reciprocal of the permeability of the core material in the linear region of the normal magnetization curve.

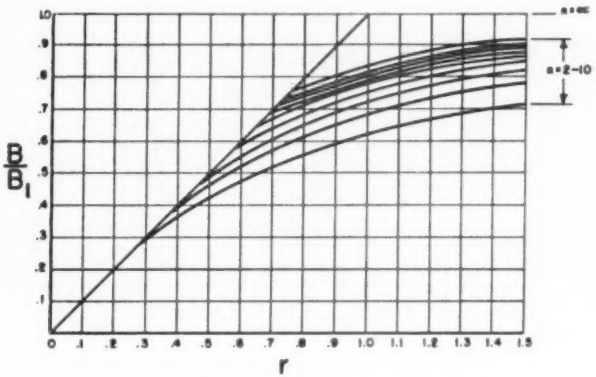


FIG. 3. Plot of B/B_1 *versus* r for various values of n.

We now obtain, from Fig. 3, the value of B/B_1 corresponding to this value of r where B is the actual flux density in the core. We then have

$$\phi = \left(\frac{B}{B_1}\right) B_1 A_c. \tag{3}$$

The applicable curve in Fig. 3 for a given core material may be determined from the equation,

$$n = \frac{\ln \dfrac{H_a - KB_a}{H_b - KB_b}}{\ln \dfrac{B_a}{B_b}}, \tag{4}$$

where (B_a, H_a) and (B_b, H_b) are any two points on the magnetization curve. Having thus determined the value of n, we have ascertained the correct plot of B/B_1 *versus* r to be used in all problems of this type for this particular core material.

III. DISCUSSION

The solution is seen to depend upon the evaluation of two constants, K and n, and the normal magnetization curve. Once these two constants are obtained, the problem is solved for all circuits of the type considered, regardless of the dimensions of the circuit.

In general, this solution permits the rapid determination of the flux with a greater degree of neatness than with trial and error type solutions.

This solution may be applied in magnetic relay design, as well as instruments, meters, and simple d-c. machines.

APPENDIX I

Derivation

The fundamental equation relating the flux density and the magnetizing force for air is,

$$H_{air} = 313\, B_{air}, \tag{5}$$

where H is expressed in ampere-turns per inch and B is given in kilolines per square inch.

Next, we assume that the normal magnetization curve of the core material may be represented with sufficient accuracy by an expression of the form,

$$H = KB + aB^n, \tag{6}$$

where $\frac{1}{K}$ is the permeability of the core material in the linear region of the normal magnetization curve, that is, that portion of the curve where saturation effects are negligible. The second term in this equation may be interpreted as the additional magnetizing force needed to produce a given flux density beyond the point where saturation is no longer negligible.

For the circuit in Fig. 1, we have,

$$\phi = B_{air}A_a = B_{core}A_c; \tag{7}$$

also

$$H_{core}L_c + H_{air}L_a = NI; \tag{8}$$

or, combining these equations, we obtain

$$a\left(\frac{\phi}{A_c}\right)^n L_c + \frac{K\phi L_c}{A_c} + \frac{313\phi L_a}{A_a} = NI. \tag{9}$$

Since saturation, for most core materials, produces a very rapid departure from the linear portion of the magnetization curve, we should expect n to be a relatively large number. Consequently, it will not be feasible to seek a direct solution by solving algebraically for ϕ.

With the idea of obtaining a practicable method, we define a dimensionless quantity, x, by the equation,

$$a\left(\frac{\phi}{A_c}\right)^n L_c = x\left(\frac{K\phi L_c}{A_c} + \frac{313\phi L_a}{A_a}\right). \tag{10}$$

Having thus defined x, we may rewrite Eq. 9 as,

$$\phi\left(\frac{KL_c}{A_c} + \frac{313L_a}{A_a}\right)(1 + x) = NI. \tag{11}$$

Next, solving Eq. 10 for ϕ, we obtain,

$$\phi = \left[\frac{A_c{}^n x}{aL_c}\left(\frac{KL_c}{A_c} + \frac{313L_a}{A_a}\right)\right]^{1/(n-1)}. \tag{12}$$

Substituting (12) into (11) gives,

$$\left(\frac{KL_c}{A_c} + \frac{313L_a}{A_a}\right)^{n/(n-1)}\left(\frac{A_c{}^n x}{aL_c}\right)^{1/(n-1)}(1 + x) = NI. \tag{13}$$

Then,

$$x^{1/n}(1 + x)^{(n-1)/n} = r, \tag{14}$$

where

$$r = \frac{NI}{\left(\frac{313L_a}{A_a} + \frac{KL_c}{A_c}\right)A_c\left(\frac{NI}{aL_c}\right)^{1/n}}. \tag{15}$$

Next, solving Eq. 11 for ϕ, we obtain,

$$\phi = \frac{NI}{\left(\frac{313L_a}{A_a} + \frac{KL_c}{A_c}\right)(1 + x)}, \tag{16}$$

or, dividing both sides by $A_c\left(\frac{NI}{aL_c}\right)^{1/n}$

$$\frac{\phi}{A_c\left(\frac{NI}{aL_c}\right)^{1/n}} = \frac{NI}{(1 + x)\left(\frac{313L_a}{A_a} + \frac{KL_c}{A_c}\right)A_c\left(\frac{NI}{aL_c}\right)^{1/n}} = \frac{r}{1 + x}. \tag{17}$$

But from Eq. 14

$$x = f(r,n) \tag{18}$$

so that,

$$\frac{\phi}{A_c\left(\frac{NI}{aL_c}\right)^{1/n}} = \frac{B}{\left(\frac{NI}{aL_c}\right)^{1/n}} = \frac{r}{1 + f(r,n)} = F(r,n), \tag{19}$$

where B is the flux density in the core.

Now let us define a fictitious flux density, B_1, such that,

$$B_1 = \left(\frac{NI}{aL_c}\right)^{1/n}. \tag{20}$$

We may now write, by substitution of Eq. 20 in 19, for a given n,

$$\frac{B}{B_1} = F(r). \tag{21}$$

We see that, for a given material, the quantity B/B_1 may be plotted as a function of r. Thus if r and B_1 are known B may be directly determined from this plot. B_1 may be obtained from the normal magnetization curve by laying off $H_1 = \frac{NI}{L_c}$ (see Fig. 2), and constructing the line AC parallel to the linear portion of the curve. The intersection of this line with the curve gives the desired value of B_1.

To prove this we note that $OACD$ is a parallelogram, hence

$$H_1 = aB_1^n = \frac{NI}{L_e} \tag{22}$$

or,

$$B_1 = \left(\frac{NI}{aL_e}\right)^{1/n}. \tag{23}$$

This expression is identical to Eq. 20.

If we wish to determine the correct curve in Fig. 3 for a given core material, we have only to calculate the value of n for this material. Taking any two points (a, b), on the magnetization curve of this material, we have, from Eq. 6

$$n = \frac{\ln \dfrac{H_a - KB_a}{H_b - KB_b}}{\ln \dfrac{B_a}{B_b}}, \tag{24}$$

where $\frac{1}{K}$ is the measured value of the slope of the normal magnetization curve in the linear region.

To conclude, then, we note that the solution is essentially the utilization of dimensionless quantities which are dependent on the geometry, excitation, etc., which, in turn, are related to each other by the plots given in Fig. 3.

NON-UNIFORM TORSION OF TAPERED I-BEAMS

BY

LAWRENCE H. N. LEE[1]

ABSTRACT

In this paper an analysis is made of the tapered I-beam in non-uniform torsion. The result of the analysis holds true for that class of I-sections having relatively high ratios of web to flange thickness. The effects of web deformation, considered by Goodier and Barton for beams of uniform cross-sections are relatively small for these ratios. Therefore, these effects are not taken into consideration in this analysis. The result is illustrated by three numerical examples.

INTRODUCTION

The problem of non-uniform torsion of an I-beam of constant cross-section was first solved by Timoshenko (1, 2),[2] who used as an example the case in which one end of the beam is built in and cannot warp. His solution was based on the consideration of the bending of the flanges in their own planes with the assumption that the relative rotation of the web to the flanges has little effect on the magnitudes of the major stresses. It was pointed out later by Goodier and Barton (3) that Timoshenko's analysis is not general enough to fit a number of end conditions. They also showed that for beams having low ratios of web to flange thickness the effects of web deformation on the distribution of stresses are significant. These effects have been experimentally verified by Kubo, Johnston and Eney (4). However, they also concluded that Timoshenko's solution adequately predicts the magnitudes of stresses developed in solid sections of ordinary dimensions under non-uniform torsion.

In the case of a tapered I-beam, the solution which takes into account the effects of web deformation would be complicated. Therefore, it was decided in this investigation to consider the case of solid sections of ordinary dimensions for which the effects of web deformation are negligible. Moreover, only the unbuckled elastic state of the tapered I-beam is considered.

PRELIMINARY CONSIDERATIONS

The tapered I-beam under consideration may be thought of as consisting of three tapered plates of rectangular cross sections with the two flanges subjected to both bending and torsion. In this case the web is assumed to take only part of the Saint Venant Torsion. Thus, a tapered plate subjected to bending and torsion is first considered.

[1] Department of Engineering Mechanics, Notre Dame University, Notre Dame, Ind.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

The exact normal stresses at a section *mn* in a wedge due to a laterally concentrated force, *P*, (see Fig. 1) may be determined by the expression (5)

$$\sigma_x = -\frac{My}{I}\left(\frac{\tan\alpha}{\alpha}\right)^3 \sin^4\psi \tag{1}$$

where $M = Px$ and I is the moment of inertia of the cross-section *mn*. For small values of α, the factor $\left(\frac{\tan\alpha}{\alpha}\right)^3 \sin^4\psi$ can be taken as being equal to unity. Then the expression for σ_x coincides with that given

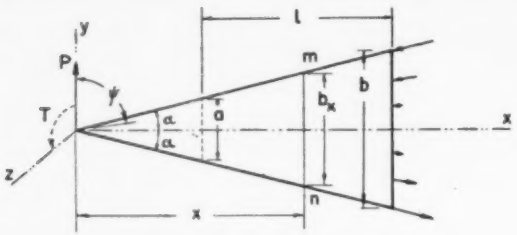


FIG. 1. Tapered plate in bending or torsion.

by the elementary beam formula. Similarly, for small values of α, the moment-curvature relationship along the center line can be closely approximated by the elementary flexural formula

$$M = EI\frac{d^2y}{dx^2}, \tag{2}$$

where E is the modulus of elasticity. The effect of shear on curvature is neglected, as usual.

The torque-rotation relationship of a tapered plate subjected to torsion has been analytically solved by Nadai (6). This relationship has also been examined experimentally in the present work. Four brass, tapered, thin plates with central angles of 2.73°, 8.23°, 12.35°, and 18.00° were tested in torsion. The experimental arrangement is shown in Fig. 2 except that the transit used in the tests was placed at a large distance from the test frame. The adjustable test frame was placed on a 32-in. diameter turn table. The axis of the tapered plate was adjusted to the vertical position at the center of the turn table. The ends of the tapered plate were each placed in position between two knife-edge plates. No pressure was applied between the knife-edge plates and the tapered plate. The torque was introduced through the pulleys and shaft shown. The shaft was mounted in ball bearings. The angle of twist of a section was measured by the amount of rotation

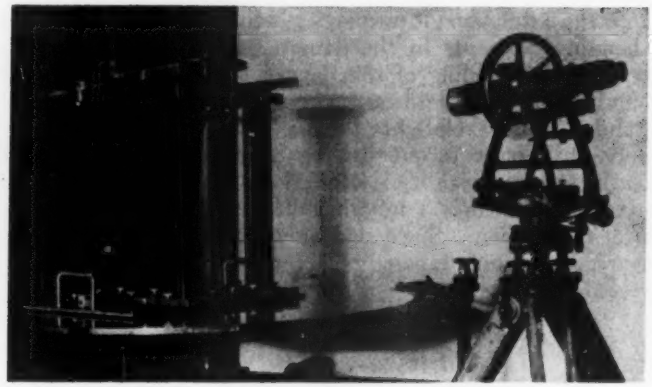


FIG. 2. Test set-up of tapered plate in torsion.

required to collimate the section with the fixed line of sight of the transit.

The results of the tests showed that, for the cases examined, the variations of the angle of twist agreed almost exactly with that determined by the modified Saint Venant torsional relationship for members under uniform torsion; that is

$$T = C\varphi' \tag{3}$$

in which T is the applied torque, φ' is the rate of change of angle of twist along the x axis, and the torsional rigidity C is considered a variable. Then, for the tapered thin plate shown in Fig. 1,

$$C = \tfrac{1}{3}Gt^3b_x, \tag{4}$$

where t is the thickness of the plate and G is the shear modulus of elasticity. Equation 3 can also be deduced from the expression given by Nadai (6). The analysis of the tapered I-beam is based on the Eqs. 2 and 3.

THE DIFFERENTIAL EQUATIONS

Figure 3 shows a bi-symmetrical tapered I-beam. The flanges and the web are converging to the point O, which is taken as the origin of the coordinate system. One end of the beam is free and subjected to an applied torque T. The other end is assumed to be fixed and cannot warp. Warping in this case varies along the beam, and torsion is accompanied by bending of the flanges. If a section including the free end is taken as a free body, the condition of rotational equilibrium requires that

$$T = T_s + T_w + T_f \tag{5}$$

where T_s is the Saint Venant torque, T_m is the sum of the x-components of the bending moments in the flanges, and T_v is the shear couple developed by the bending of the flanges. If it is assumed that the flanges and the web twist through the same angle, then the values of T_s, T_m, and T_v can be related to the angle of twist φ.

The Saint Venant torque can be expressed by Eq. 3. In this equation the torsional rigidity is a function of the geometry of the cross-section, which in turn is a function of the distance x indicating the position of the section. Since the tapered I-beam may be considered as an aggregate of three tapered plates, the torsional rigidity may thus be expressed by

$$C = k_s x, \tag{6}$$

where

$$k_s = \frac{G}{3l_o}(ht_w^3 + 2bt_f^3). \tag{7}$$

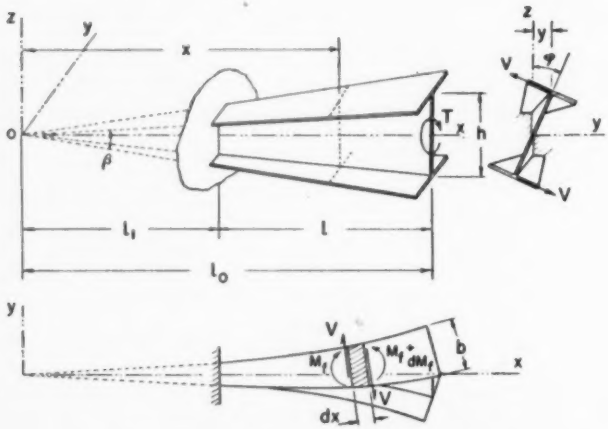


FIG. 3. Non-uniform torsion of tapered I-beam.

Here, t_w and t_f are the thicknesses of the web and the flanges, respectively. By combining Eqs. 3, 6 and 7, we obtain

$$T_s = k_s x. \tag{8}$$

The bending moment M_f in the flanges may be expressed by Eq. 2. As shown in Fig. 3, the lateral deflection y of the flange centroid can be written as

$$y = \frac{h}{2l_o}\varphi x. \tag{9}$$

The moment of inertia of a cross-section of one flange is also a function of x, being given by

$$I = \frac{1}{12}\frac{b^3 t_f}{l_o^3}x^3. \tag{10}$$

Substituting Eqs. 9 and 10 into Eq. 2, we find

$$M_f = \frac{E}{24}\frac{b^3 t_f h}{l_o^4}x^3\,(2\varphi' + x\varphi''). \tag{11}$$

The sum of the x components of the bending moments in the flanges is

$$T_m = k_f x^3\,(2\varphi' + x\varphi'') \tag{12}$$

where

$$k_f = \frac{E}{24}\frac{b^3 t_f h^2}{l_o^5}. \tag{13}$$

The shear forces, V, in the flanges are related to the bending moment, M_f by the expression

$$V = \frac{dM_f}{dx}. \tag{14}$$

The couple produced by the positive shear forces as indicated in Fig. 3 has a negative sense of rotation; thus

$$T_v = -\frac{Vh}{l_o}x. \tag{15}$$

On substitution of Eqs. 11 and 14 into 15, we have

$$T_v = -k_f\,[x^5\varphi''' + 6x^4\varphi'' + 6x^3\varphi'], \tag{16}$$

where φ'' and φ''' are the second and the third derivatives of φ with respect to x.

With the values of T_s, T_m, and T_v determined, the equilibrium equation of torsion then becomes

$$\varphi''' + \frac{5}{x}\varphi'' + \left(\frac{4}{x^2} - \frac{\mathrm{K}}{x^4}\right)\varphi' = -\frac{T}{k_f x^5}, \tag{17}$$

where

$$\mathrm{K} = k_s/k_f. \tag{18}$$

SOLUTION

One method used in solving a differential equation with variable coefficients is through the use of power series. This method is used in this analysis. The point $x = 0$ is a singular point having the nature

of an irregular singularity (7). For this case there is no solution in ascending power series. The solutions of the reduced differential equation are determined by assuming a descending power-series solution of the form

$$\theta = \sum_{n=0}^{\infty} a_n x^{s-n} \tag{19}$$

in which $\theta = \varphi'$.

The values of a_n and the values of s can be determined by substituting the power series for θ and equating coefficients. The indicial equation obtained from the substitution yields two roots for the values of s, differing by an integer. The series solutions resulting from the use of these two roots are the same. The second solution is found by assuming

$$\theta_2(x) = \theta_1(x) \log x + \sum_{n=0}^{\infty} b_n x^{s'-n}. \tag{20}$$

The coefficients are determined by substitution in the reduced equation. The complementary solution can also be found by the method of substitution of a series solution of the form given in Eq. 19 into the complete differential equation. The general solution is then

$$\varphi = \varphi_0 - (A + B \log_e x) \frac{1}{x} \sum_{n=0}^{\infty} \frac{1}{(2n+1) \cdot 4^n \cdot (n!)^2} (S_x)^n$$

$$- \frac{B}{x} \left[\sum_{n=0}^{\infty} \frac{1}{(2n+1)^2 \cdot 4^n \cdot (n!)^2} (S_x)^n + \sum_{n=1}^{\infty} \frac{N_n}{(2n+1) \cdot 4^n \cdot (n!)^2} (S_x)^n \right]$$

$$+ \frac{T}{2k_f x^2} \sum_{n=0}^{\infty} \frac{4^n (n!)^2}{(n+1) \cdot [(2n+1)!]^2} (S_x)^n, \tag{21}$$

where

$$N_n = (\cdots\{[(1 \cdot 2 + 1)3 + 2!]4 + 3!\}5 + \cdots)n + (n-1)! \tag{22}$$

φ_0 is a constant expressed in radians, A and B are two dimensional constants expressed in units of length, and

$$S_x = \frac{K}{x^2} = \frac{2C}{EI\beta} \tag{23}$$

in which β is the central angle between the two flanges measured in radians. S_x is a dimensionless number which indicates the geometrical and material properties of a section at a distance x from the origin.

The rate of change of the angle of twist is obtained by differentiating Eq. 2 with respect to x. Thus

$$\theta = (A + B \log_e x) \frac{1}{x^2} \sum_{n=0}^{\infty} \frac{1}{4^n (n!)^2} (S_x)^n + \frac{B}{x^2} \sum_{n=1}^{\infty} \frac{N_n}{4^n (n!)^2} (S_x)^n - \frac{T}{k_f x^3} \sum_{n=0}^{\infty} \frac{4^n (n!)^2}{[(2n+1)!]^2} (S_x)^n. \quad (24)$$

Substituting Eq. 22 and its derivative into Eq. 11 we find the bending moment in the flanges;

$$M_f = \frac{T}{\beta} \sum_{n=0}^{\infty} \frac{4^n (n!)^2}{[(2n)!][(2n+1)!]} (S_x)^n - \frac{k_f x}{\beta} \left\{ (A + B \log_e x) \sum_{n=0}^{\infty} \frac{2n}{4^n (n!)^2} (S_x)^n + B \left[\sum_{n=1}^{\infty} \frac{2nN_n}{4^n (n!)^2} (S_x)^n - \sum_{n=0}^{\infty} \frac{1}{4^n (n!)^2} (S_x)^n \right] \right\}. \quad (25)$$

The power series given in Eqs. 20, 22, and 23 are uniformly and absolutely convergent for all values of S_x. For small value of S_x, the series converge rapidly. When S_x is large the series converge slowly.

The constants φ_0, A, and B in the foregoing equations can be determined from the end conditions. For the beam shown in Fig. 3, the conditions at the fixed end are $x = l_1$, $\theta = 0$, $\varphi = 0$. At the free end, the condition is $x = l_0$, $M_f = 0$. These conditions yield three equations from which φ_0, A and B can be determined in terms of T.

NUMERICAL EXAMPLES

Figure 4 shows the results of calculations for three aluminium I-beams, beams A, B and C. Beam A has a uniform cross-section of $h = 3$ in., $b = 2.50$ in., $t_w = t_f = 0.25$ in. and a length of 10 in. Beams B and C are tapered and have the same length of 10 in. The large ends of beams B and C have the same cross-section as that of beam A. The tapers of beams B and C are indicated by the dimensions: for beam B, $\beta = 0.10$ rad, $l_1 = 20$ in., $l_0 = 30$ in.; for beam C, $\beta = 0.15$ rad, $l_1 = 10$ in., $l_0 = 20$ in. The modulus of elasticity and Poisson's ratio are taken as $E = 10 \times 10^6$ psi. and $\mu = 0.32$. Each beam is considered to be fixed at the large end and subjected to a torque of 1000 in-lb. at the small end.

The values of θ, φ, T_s, and M_f for beam A are determined by the expressions given by Timoshenko (1, 2). The corresponding values for beams B and C are computed by the foregoing series solutions. The series functions must be carried out with six- or seven-place accuracy in order to obtain results significant to the third place in θ, φ, T_s, and M_f. It would be helpful if a table of the values of these functions for the ordinary range of S_x were established.

Figure 4 shows that beams B and C have high values of T_s, which is to be expected because of the smaller resistances provided by their flanges. It is also apparent from these curves that the flange moments of beams B and C are lower than that of beam A. However, the bending stresses in the flanges of beams B and C are higher than those in A, because their sections have smaller values of moment of inertia.

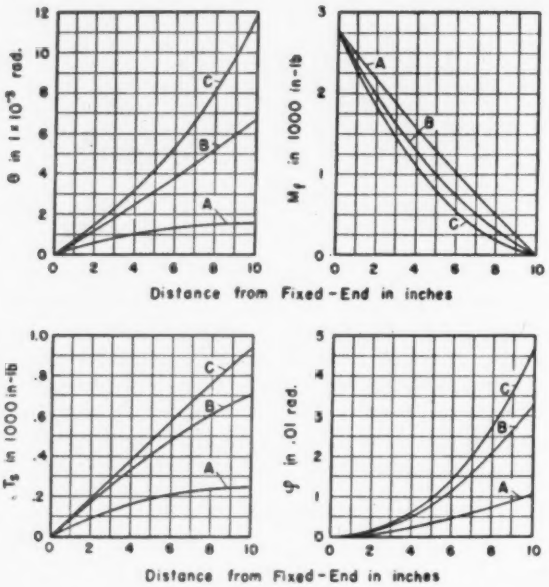


FIG. 4. Numerical examples.

REFERENCES

(1) S. TIMOSHENKO, "Strength of Materials," Vol. 2, second edition, New York, D. Van Nostrand Company, Inc., 1941, pp. 282–288.

(2) S. TIMOSHENKO, "Theory of Bending, Torsion and Buckling of Thin-Walled Members of Open Cross Section," JOUR. FRANKLIN INST., Vol. 239, pp. 249–268 (1945).

(3) J. N. GOODIER AND M. V. BARTON, "The Effects of Web Deformation on the Torsion of I-Beams," *J. Appl. Mech.*, Vol. 11, pp. A-35–40 (1944).

(4) G. G. KUBO, B. G. JOHNSTON AND W. J. ENEY, "Non-Uniform Torsion of Plate Girders," *ASCE Proceedings*, Separate No. 449, June, 1954, 28 pp.

(5) S. TIMOSHENKO AND J. N. GOODIER, "Theory of Elasticity," second edition, New York, McGraw-Hill Book Company, Inc., 1951, p. 98.

(6) A. NADAI, "Elastishe Platten," Berlin, Springer, 1925, p. 203.

(7) E. L. INCE, "Ordinary Differential Equations," New York, Dover Publications, Inc., 1926, p. 160.

THE ACADEMY BELL: THE FRANKLIN INSTITUTE AND OLD PHILADELPHIA*

BY

JOSEPH SAMUEL HEPBURN[1]

THE ACADEMY BELL

Between 221 and 223 Market Street, Philadelphia, a public alley extends northward to Church Street. On the west side of that alley formerly was a tablet[2] with this inscription:

IN THIS ALLEY CALLED GRINDSTONE

WAS LOCATED THE UNION FIRE

COMPANY—THE FIRST ORGANIZED

GROUP OF FIREMEN IN AMERICA.

FOUNDED BY

BENJAMIN FRANKLIN

1736

ERECTED BY THE

NATIONAL ASSOCIATION OF MUTUAL INSURANCE COMPANIES

1936

According to Wainwright (1),[3] the Union Fire Company, organized in 1736, was Philadelphia's first volunteer fire force[4]; the Fellowship

* Presented before the City History Society of Philadelphia, February 15, 1955.

[1] Archives Researcher, The Franklin Institute; Professor of Chemistry and Research Associate in Gastroenterology, Emeritus, The Hahnemann Medical College and Hospital of Philadelphia; President, City History Society of Philadelphia.

[2] On April 17, 1956, *The Philadelphia Inquirer* (Final City Edition, p. 23) reported that this tablet had been stolen from its place in Grindstone Alley.

[3] The boldface numbers in parentheses refer to the references appended to this paper.

[4] The Union Fire Company was located in 1750 on the east side of Grindstone Alley near Church Alley (now Church Street), according to Grant Miles Simon's map, "Part of Old Philadelphia," published by the American Philosophical Society for its *Transactions*, New Series, Vol. 43 (1953). On "A Map of the City of Philadelphia Showing the Location of the Volunteer Fire Companies" about 1825–1830 (copyright by The Insurance Company of North America 1938), the Union Fire Company is shown at First (now Front) and High (now Market) Streets.

Company was organized in 1738, the Hand in Hand Company in 1742, and other companies at later dates.

The minute books of the Union Fire Company contain its articles of association, signed by Benjamin Franklin and his associates on December 7, 1736, a record of its meetings until its dissolution by vote of its members on December 7, 1843, and a summary of the winding-up of its affairs. In them the Fire Bell or Academy Bell is mentioned in the minutes of over thirty meetings.

Portrait of Benjamin Franklin as a member of the Union Fire Company, painted by C. O. Wright in 1795, now in the collection of The Insurance Company of North America. His helmet bears the insignia of the Union Fire Company; and its Engine House is depicted in the background.

On July 30, 1750, a proposal was made to purchase a Fire Bell out of the money arising by the Fines and Forfeitures of the Company. On August 27, 1750, twenty-five pounds were appropriated toward purchasing a Fire Bell of about 500 pounds weight; the resolution concluded with the clause "that Philip Syng and Benj. Franklin, apply to some of the other Fire Companies to know what they will contribute toward such a Bell." On August 30, 1751, twenty-five pounds were ordered paid to Daniel Benezet "who undertakes to send the same to England with such Other Money as shall be put into his hands by the

hand in hand fire Comp., to purchase a bell of five hund'd. Weight agreeable to a former Minute of this Comp., which bell is to have this Inscription cast on it, in Capitals by the Union & Hand in Hand Companies." On February 24, 1752, arrival of the bell is noted, also that a balance of sixteen pounds, two shillings is due to Daniel Benezet for the same. "Benjamin Franklin & Phillip Syng are appointed a Committee to Waite on the Hand in Hand Company to consult on a proper place to Erect the Bell and Inform that Company the opinion of this Company—To place it at the Academy untill the two Companys

Courtesy of the American Philosophical Society,

The Academy Bell

please to Remove it to another place." On March 29, 1752, this Committee reported that the Hand in Hand Fire Company "approve of the Bell's being hung at the Academy" and will pay one-half of the balance due on the bell. The Union Fire Company at once ordered that one-half of the balance due to Daniel Benezet be paid from its funds.

The University of Pennsylvania (successor to the Academy) moved to its new site on Ninth Street from Market Street to Chestnut Street (now the site of the United States Court House) in the period 1800–1802 (2).

Numerous entries in the minutes of the Union Fire Company between May 5, 1802 and October 28, 1807 imply negotiations between

that Company and the Hand in Hand Fire Company on the one hand, and the Trustees of the University on the other hand, concerning the Fire Bell. On October 28, 1807, "Edward Pennington from the Committee appointed to procure the Bell belonging to the Union and Hand in Hand Fire Companies reported that he had received said Bell from the Trustees of the University." A plan to use the bell as a municipal fire bell is suggested. On October 5, 1808, it is recorded that the "Bell is at present in Edward Pennington's Sugar House Store."[5]

On January 18, 1809, a letter from Thomas Cumpston as Church Warden requested the loan of the bell. A committee was appointed to join with one from the Hand in Hand Company "to loan the Bell which is the joint property of the Two Companies to the Church Wardens of St. James' Church on such terms as they may think proper, provided that the Bell shall be rung upon all occasions of Fire."

On January 3, 1810, this committee reported and accompanied their report with a receipt, dated November 14, 1809, and signed by "Thos. Cumpston Church Warden of the United Episcopal Churches in the City of Philada." for "a Bell formerly known as the Academy Bell . . . for the purpose of hanging in the Tower of St. James's Church to be rung as an Alarm bell in the time of Fire and other Alarm and also to be used as a Church Bell for that Church." The receipt recognized the bell as the "joint property" of the two fire companies, and "to be returned to them on their joint demand."

The exact status of Cumpston and of St. James's (also written St. James') Church is revealed by these facts. Thomas Penn and Richard Penn, the Proprietaries of Pennsylvania, on June 24, 1765, granted a charter incorporating "The Rector, Church-Wardens and Vestry-Men of the United Episcopal Churches of Christ-Church and St. Peter's Church, in the city of Philadelphia, in the Province of Pennsylvania" (3). On Easter Monday, April 25, 1791, twenty vestrymen were elected under this charter, ten for each Church. Thomas Cumpston was one of the group from Christ Church (4). He served as a Church Warden of the "United Churches" from 1793 to 1814 (3). In the Philadelphia Directory for 1793 he is listed as

[5] The minutes of the Union Fire Company record that Edward Pennington junr. was elected to membership on November 4, 1795, and attended the meeting and signed the articles on December 2, 1795. He acted as clerk (secretary) of the meeting of May 4, 1796 and signed its minutes as "Edw Penington Jr. Clerk." Edward Penington, Jr., sugar refiner was an original member of The Franklin Institute. Its *Account Book A* shows payment of dues in 1824 and 1825 and, in 1826, has the entry "Dead." Thomas Wilson's "The Philadelphia Directory and Stranger's Guide" for 1825 (p. 109) lists Edward Pennington, sugar refiner, 155, dwelling 139 Sassafras (now Race) Street. Robinson's "Philadelphia Directory" for 1808 lists Edward Pennington, sugar refiner, 155 Sassafras Street, and states that Crown (now Lawrence) Street extended "from 155 Sassafras to above Wood." John F. Watson, in his *Annals of Philadelphia and Pennsylvania, in the Olden Time*, Vol. 3, p. 304 (1884), mentions Pennington's sugar house at the northeast corner of Crown and Race Streets. Apparently the Academy Bell was stored here, 1807–1809. The segment of Lawrence Street from Race Street to Florist Street (the southern side of the Benjamin Franklin Bridge) no longer exists.

"Cumpston Thomas, shopkeeper, 74, High St." (5). The annual city directories for 1797–1800 (6) show that Cumpston was a member of the Select Council of Philadelphia during those years. He is described as a merchant then and in subsequent directories as late as 1819.

St. James's Church was erected by the United Churches in 1807 on the northeast corner of Seventh and St. James (now Commerce) Streets, and occupied that building until November 22, 1869 (3,7,8).

Upon petition to the General Assembly of Pennsylvania, the proprietary charter of 1765 (3) was enlarged and altered on March 19, 1810 (3,9) the corporation becoming "The Rector, Church Wardens and Vestrymen of the United Churches of Christ Church, St. Peter's Church and St. James's Church, in the City of Philadelphia." Upon amicable agreement and petition to the General Assembly of Pennsylvania, St. James's Church became a separate corporation with a legislative charter as "The Rector, Church Wardens and Vestrymen of St. James' Church in the City of Philadelphia" on February 5, 1829 (10).

The minute books of the Union Fire Company show that, at its final meeting on December 7, 1843, several resolutions were adopted, one of which was:

"Resolved, that the interest of this Company in the Bell at St. James' Church, be presented to the Corporation of that Church for the use thereof."

Other resolutions gave the funds of the Union Fire Company to the Union Benevolent Association, and directed deposit of "the Books of Minutes and Records of this Company" in the library of the Library Company of Philadelphia where they have been consulted by the author.

In the summary of the winding-up of the affairs is a copy of a letter sent to I. (actually James) H. Bradford, one of the Wardens of St. James's Church on April 6, 1844 by John White, who was chairman at the final meeting of the Union Fire Company; it contains a copy of the above resolution concerning the bell. Receipt of this letter is recorded in the minutes of a stated meeting of The Rector, Church Wardens and Vestrymen of St. James's Church held April 22, 1844.

Browne (7) speaks of this bell in the tower of St. James's Church on Seventh Street, and relates that it was installed in the belfry of the school building when the new church buildings were erected in 1870–1871 at the northwest corner of Walnut and Twenty-second Streets. The Church occupied this site until 1945, and is now located at Green Ridge, Pa. (11).

This bell now is in the basement of the Hare Building at the University of Pennsylvania. The legend, cast into it, is in two lines and reads:

GIVEN BY THE UNION & HAND IN HAND FIRE COMPANIES 1752 THO^{s}. LESTER MADE ME

According to Turner (12) the bell is 23 inches high, has a circumference of 65 inches at its base, and "was returned to the University of Pennsylvania in 1945."

Since Christ Church and St. Peter's Church have been mentioned as separate churches, it should be noted that, by amicable agreement and petition to the General Assembly of Pennsylvania, they were made separate corporations by an Act of Assembly approved January 13, 1832, and styled respectively, "The Rector, Church Wardens and Vestrymen of Christ Church in the City of Philadelphia" and "The Rector, Church Wardens and Vestrymen of St. Peter's Church in the City of Philadelphia" (13).

THE FRANKLIN INSTITUTE AND OLD PHILADELPHIA

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts was founded at a meeting in the County Court House on February 5, 1824 (14) and was incorporated by a special Act of the General Assembly of the Commonwealth of Pennsylvania approved March 30, 1824 (15). Samuel Vaughan Merrick has been described as "the acknowledged Founder of the Institute"; he was ably aided by William H. Keating (16).[6] This Court House still stands on the southeast corner of Chestnut and Sixth Streets, and is now known as Congress Hall since the Congress of the United States met in it from December 6, 1790 to May 14, 1800.

In 1824, the following courts were held in this building (17): Circuit Court of the United States, District Court of the United States, Supreme Court of Pennsylvania for the Eastern District, and the following courts for the City and County of Philadelphia: District Court, Court of Common Pleas, Orphan's Court, Court of Oyer and Terminer and General Gaol Delivery, Court of Quarter Sessions. The District Court for Philadelphia was abolished by the present constitution of Pennsylvania (18). The law school of the University of Pennsylvania occupied this building 1895–1900 (19).

The early history of The Franklin Institute is associated with other historic buildings of Philadelphia: The Hall of the American Philosophical Society, Carpenters' Hall, and the Academy.

The meeting at which the founding of The Franklin Institute was planned was held in "Philosophical Hall" on December 29, 1823 (20). It was attended by Merrick, Keating, and a number of their colleagues, one of whom was M. W. Baldwin.

[6] On March 8, 1870, Hector Orr, in a letter to the Managers of The Franklin Institute concerning the death of Isaac Ashmead during the preceding week stated: "It was he who suggested the name of *Franklin* as the distinctive word in the title of the association," and added "I send this as authentic information concerning a much esteemed friend." The *Account Books* of the Institute reveal that both Ashmead and Orr, like Franklin, were printers, and that Ashmead became a member in 1831, a life member in 1832; Orr a member in 1832, a life member in 1837.

Carpenters' Hall is noted as the meeting place of the First Continental Congress. Its first story was occupied by The Franklin Institute from December 12, 1824 to April 12, 1826 (21). Use had been made of Carpenters' Hall by the Institute at earlier dates. The Institute's first exhibition of products of American industry was held there on October 18–20, 1824. Meetings of the Institute were held there on April 15 and October 21, 1824 (22), also all meetings of its Board of Managers in 1824, beginning on February 26 (23). The Board met in the then new Hall of The Franklin Institute (13, 15, 17 South Seventh Street) in March, 1826, and the Institute met there on April 20, 1826 (24).

In its early days, The Franklin Institute also used the building known as the New Building, the Tabernacle, the Academy, and the Old College. The Institute met there on July 15, 1824 (25). The first series of lectures before the Institute was delivered there in 1824 (26, 27).

Articles on these historic buildings have been published: Congress Hall by Edward M. Riley (28), Philosophical Hall by William E. Lingelback (29), Carpenters' Hall by Charles E. Peterson (30), the Academy by William L. Turner (12), and The Franklin Institute by Henry Butler Allen (31). Of these buildings, all save the Academy are still standing.

Relics of the Academy exist. Its corner stone, bearing the inscription "I. P. 1740. J.C.," has been preserved in the Union Methodist Church of Brookline, Delaware County, Pa. (32). The inscription includes the date (1740) and the initials, in Latin, of *In Pace Jesu Christi*, that is In the Peace of Jesus Christ. The library of the University of Pennsylvania contains books from the Academy library, and a model of the Academy building. A model of the two buildings (the Academy and the Dormitory and Charitable School) is also in the university library; and a painting of the two buildings is in the Edgar Fahs Smith Memorial Collection in the History of Chemistry at the university. This Collection also contains a hand bell and two antique chairs, used in the Academy, preserved by Albert Monroe Wilson, known to fifty classes of Pennsylvania men as "Pomp," and presented by him to Provost Edgar F. Smith. The "Academy Bell" now possessed by the University of Pennsylvania, is not only a relic of the Academy, but is also linked with Benjamin Franklin, as related above.

From its earliest days, the membership of The Franklin Institute has been drawn from all the groups represented by these historic buildings: professional men, savants, technologists, artisans, educators. This diversity of vocation of its members has broadened the vision of the Institute, enabled it to sense the needs of the community, and to serve the community, and also the nation, accordingly, by its library, JOURNAL, lectures, exhibitions, schools, museum, researches, and awards.

REFERENCES

(1) NICHOLAS B. WAINWRIGHT, "A Philadelphia Story: The Philadelphia Contributionship for Insurance of Houses from Loss by Fire," Philadelphia, 1952, p. 21.
(2) EDWARD P. CHEYNEY, "A History of the University of Pennsylvania 1740–1940," Philadelphia, 1940, pp. 180–182.
(3) BENJAMIN DORR, "A Historical Account of Christ Church, Philadelphia, from Its Foundation, A. D. 1695, to A. D. 1841; and of St. Peter's and St. James's until the Separation of the Churches," New York and Philadelphia, 1841, pp. 349–358, 299–300, 219–221.
(4) Minute Book of the Corporation of the United Episcopal Churches of Christ Church and St. Peter's Church in the City of Philadelphia 1784–1815, p. 58.
(5) JAMES HARDIE, "Philadelphia Directory and Register," Philadelphia, 1793, p. 31.
(6) CORNELIUS WM. STAFFORD, "Philadelphia Directory," 1797–1800.
(7) A. E. BROWNE, "A Sketch of St. James's Parish from Its Foundation in 1807 to 1899," 69 pages.
(8) "Consecration of St. James's P. E. Church, N. W. cor. Twenty-second and Walnut Sts. in the City of Philadelphia. 1880." 14 pages.
(9) "Laws of the Commonwealth of Pennsylvania from October 14, 1700," Philadelphia, John Bioren, Vol. 5, p. 113 (1812).
(10) *Laws of the General Assembly of the State of Pennsylvania*, Session of 1828–1829, pp. 26–32.
(11) *Journal of the Convention of the Protestant Episcopal Church in the Diocese of Pennsylvania* Vol. 161, p. 152 (1945); Vol. 162, pp. 146, 196 (1946); Vol. 163, p. 144 (1947).
(12) WILLIAM L. TURNER, *Transactions of the American Philosophical Society*, New Series, Vol. 43, pp. 179–186 (1953).
(13) *Laws of the General Assembly of the State of Pennsylvania*, Session of 1831–1832, pp. 17–24.
(14) Franklin Institute, Minutes of Board of Managers, Book A, pp. 2–8 (1824).
(15) *Acts of the General Assembly of the Commonwealth of Pennsylvania*, Session of 1823–1824, pp. 206–208.
(16) FREDERICK FRALEY, in "Commemorative Exercises at the Fiftieth Anniversary of The Franklin Institute," 1874, pp. 11–42.
(17) H. C. CAREY AND I. LEA, "Philadelphia in 1824," pp. 133–135 (1824).
(18) "Constitution of the Commonwealth of Pennsylvania, 1874," Article V, Section 1, and Schedule, Sections 11, 21.
(19) George E. Nitzsche, "University of Pennsylvania: Its History, Traditions, Buildings and Memorials," 5th edition, 1914, p. 159.
(20) Franklin Institute, Minutes of Board of Managers, Book A, p. 1 (1823).
(21) "The Carpenters' Company of the City and County of Philadelphia," Philadelphia, 1887, p. 63.
(22) Franklin Institute, Minutes of Meetings, Book A, pp. 3, 4 (1824).
(23) Franklin Institute, Minutes of Board of Managers, Book A, pp. 11–39 (1824).
(24) FRANKLIN JOURNAL, Vol. 1, pp. 253–254 (1826).
(25) Franklin Institute, Minutes of Meetings, Book A, p. 4 (1824).
(26) Franklin Institute, Minutes of Board of Managers, Book A, p. 20 (1824).
(27) Minutes of the Trustees of the University of Pennsylvania, Vol. 7, pp. 66, 69 (1824).
(28) EDWARD M. RILEY, *Transactions of the American Philosophical Society*, New Series, Vol. 43, pp. 27–30 (1953).
(29) WILLIAM E. LINGELBACH, *Ibid.*, pp. 43–69 (1953).
(30) CHARLES E. PETERSON, *Ibid.*, pp. 96–128 (1953).
(31) HENRY BUTLER ALLEN, *Ibid.*, pp. 275–279 (1953).
(32) H. S. J. SICKEL, "The Historic Cornerstones of Union Methodist Church in Brookline, Del. Co., Pa.," 2nd edition, 1953, 8 pages.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS

INTERCONNECTION OF ELECTRONIC COMPUTERS

Data-processing shared by two interconnected electronic digital computers has been successfully performed at the National Bureau of Standards. SEAC and DYSEAC, two high-speed computers designed and built at the Bureau, worked cooperatively on a common task to demonstrate program-controlled machine intercommunication in which coordinated programs were read into both machines. The problem simulated a situation where stock transaction reports are tabulated and summarized for fiscal accounting, and then forwarded for posting to inventory control records elsewhere. The experiments were carried out by the Bureau's data processing systems laboratory as part of a cooperative program with the Navy Bureau of Supplies and Accounts to investigate the application of electronic techniques to the problems of supply management. The experiments showed that two digital computers need not have identical operating characteristics to work together, provided that one of them has the necessary control flexibility.

Typical applications of digital computers as data processors involve replacement of many small specialized machines by a single automatic system. However, for massive paper-handling operations, or for large-scale activities requiring the processing of the same data for different purposes at different locations, the use of more than one high-speed data processor may be necessary. For instance, in the far-flung supply organizations of the armed services, expediting flow of information is essential to efficient supply management. Automatic communication between machines has been foreshadowed by direct input and output provisions so that the computer continues with other useful work while transfers of information between it and external devices are in process, and by tape-processing devices where search is under the program control of a computer. In this example, however, the interconnection is between a computer serving as the nucleus of a processing system and other parts of the same system.

Most general-purpose electronic computers employ a generally compatible digital language, can receive and transmit data in the form of electrical signals via standard communication channels over any desired distance, and can alter the course of processing programs in accordance with new or revised information. It should therefore be possible to interconnect two or more general-purpose machines so that they can cooperate on a common task. For example, a versatile large-capacity data-processor at a materiel control center might receive data

fed to it automatically by smaller computers located at various supply depots. The supervisory processor (at the center) might so control the system-wide processing that it would accept data from each of its reporting sources in a scheduled sequence but would also be free to accept and handle priority requests for supply action from any of the depots at any time.

For the kind of interaction where both information and exchanges of control are transferred between computers, the question of programmed control versus automatic interruption is particularly important. Programmed control depends to a considerable extent on human anticipation of when and how the interchanges should occur; however, if two or more systems are to interact automatically without human intervention, provision must be made for automatic interruption of a program in process in order to turn to the new information just received from another system. DYSEAC provides such interruption properties.

DYSEAC was designed at the National Bureau of Standards for the Department of Defense to serve as the nucleus of a generalized feedback control network. This computer incorporated a number of operating features enabling it to respond automatically to information from remote external devices. These operating features include manual-monitor facilities, program control flexibility, and special input-output controls. Together they provide DYSEAC with unusual properties of concurrent operation, self-regulation, and interruptibility which enable it to interact effectively with another computer.

During a period of three weeks the two machines, SEAC and DYSEAC, were available for experiments in interconnection. The program chosen for the experiment was a new method of sorting, merging, and posting of records. In the problem, stock transaction reports were tabulated and summarized by SEAC, then forwarded to DYSEAC for posting. In the SEAC program for running this problem, as detail items were identified as belonging to each file section in a scheduled order they were transferred to DYSEAC for posting there. In addition, after each complete set of detail items for a particular file section had been processed, SEAC transmitted a special end-of-set flag to DYSEAC. The coordinated DYSEAC program called for (1) responding to the SEAC transmitted signal, (2) reading-in the message from SEAC, (3) determining whether the message was a detail item or an end-of-set flag, and (4) either tallying the appropriate master file item in the first case, or reading out one file section and reading in the next in the case of the flag.

A cable between the SEAC building and the trailer van housing DYSEAC provided interconnection through a regular input-output terminal of each machine. Information transfers were initiated and terminated by transmission of control signals between the two machines.

Whenever a SEAC output instruction called for selection of the particular output used for transmission to DYSEAC, a 62-volt preparatory signal was sent from the SEAC external selector unit to DYSEAC. This signal activated appropriate monitor operations in DYSEAC. As soon as DYSEAC was ready to accept the data, it transmitted a 62-volt signal to SEAC. Only upon receipt of this signal was SEAC able to proceed with its next instruction. In effect, SEAC continued trying to complete this output instruction until DYSEAC signalled readiness to accept the transfer.

This dual machine interconnection utilized both the special program control and the manual-monitor features of DYSEAC. In terms of program control, DYSEAC is a three-address automatically sequenced machine; choice between one of two counters as the source of the address of the actual next instruction is determined by control-code digits in the instruction being executed at any operating time. In addition, a special address-storage register can serve to locate the next instruction when new information or new instructions are to be interpolated into a program that is being processed, as in the case of manual-monitor operations.

Manual-monitor operations are those that are carried out by the machine when certain prespecified conditions arise in the course of the machine's internal program and simultaneously in external switch settings. The switch settings are controlled either by the machine operator or by d-c voltage signals originating in external devices at any distance from DYSEAC. Thus, the machine can monitor its internal program to determine precisely when special operations requested by an external source are to be performed.

If the switch settings that are controlled by d-c voltages from the external device indicate that the device is ready, DYSEAC will then carry out the indicated operation, such as direct loading of one or more memory locations, and select its next instruction from the location specified by the address-storage register. The instruction selected in this manner then indicates in its program-control digits which of the two counters is to be used next. In this way, it can either return DYSEAC to a program that had been discontinued during the interruption or initiate an entirely new sequence of operations.

For the DYSEAC–SEAC interconnection, monitor switch settings were arranged so that upon receipt of the preparatory signal from SEAC, DYSEAC at its next breakpoint read in one information word to a predetermined memory address and took its next instruction from the location indicated in the address storage register. This next instruction was a "file" order which recorded both counter settings, reset the proper counter to the initiation of the routine for the processing of the data from SEAC and transferred control to that counter. Upon completion of the processing of any one set of data from SEAC,

DYSEAC would return to the sequence of operations it had been performing immediately prior to each interruption.

When the coordinated programs had been read into both machines, SEAC was set to run but was inhibited by a control signal from DYSEAC. When DYSEAC had completed reading in the first file section and had proceeded to other independent operations, a release of control enabled SEAC to start. As soon as the SEAC-processed data were ready for posting, they were converted to the proper format for DYSEAC, transmitted, and checked by DYSEAC to see whether there had been garbling in transmission. The receipt of data simulating a detail item resulted in a tally count for the appropriate master item in the file section.

Several runs of the shared program were successfully made, and the "posted" file sections were printed out on a DYSEAC magnetic wire cartridge. These results clearly demonstrated the ability of DYSEAC to respond to the monitor signals originating in SEAC and to interrupt its program in order to receive and process the detail data from SEAC. The two machines were thus made to work cooperatively on the common task that involved preliminary processing of data by SEAC, transmission of these data and program information from SEAC to DYSEAC, and further processing by DYSEAC. DYSEAC worked on an independent sequence of typical machine operations, simulating a concurrent program, during the intervals in which it waited for SEAC to transmit data.

Only a limited form of master-slave relationship was demonstrated. Only one of the two machines, DYSEAC, had the flexible system design features that provided for multiple program processing and interruptibility necessary in the interdependent system. However, this limited experiment did demonstrate the significant fact that two machines need not have identical capabilities and characteristics in order to share a common data-processing program, provided that one machine has the necessary flexibility. The one machine that is capable of multiple-program processing with interruptibility can receive and process data fed directly to it from one or more external sources and can therefore share its high-speed memory, computing ability, and output facilities with remotely located external devices, including other computers with different characteristics.

ED. NOTE: For further technical information, see "The Interconnection of Two Digital Computers," by M. E. Stevens, AIEE Conference Paper CP No. 55–736 (1955); "DYSEAC, the New NBS Electronic Computer," *NBS Tech. News Bull.*, Vol. 38, p. 134 (1954); "SEAC, the NBS Electronic Automatic Computer," *Tech. News Bull.*, Vol. 34, p. 121 (1950).

THE FRANKLIN INSTITUTE

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1955

On behalf of the Board of Managers I have the honor to present to the members of The Franklin Institute the 131st Annual Report of the condition of its affairs as called for by the by-laws.

The object of The Institute according to the charter granted by the Commonwealth of Pennsylvania on March 30, 1824, to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, was the promotion and encouragement of manufactures and the mechanic and useful arts, by the establishment of lectures on the sciences connected with them, by the formation of cabinets of models, minerals, machines, materials, and products, by exhibitions, and premiums, by a library, and by all such measures as may be judged expedient.

In this 20th century we might well change the language in which these objects were set forth by our founders, but we would not change at all their basic essence.

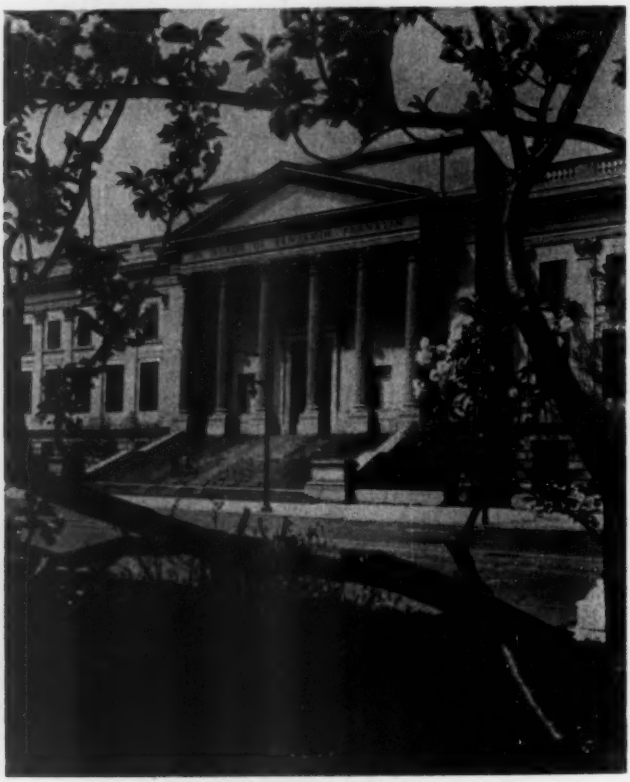
LECTURES

We are still conducting lectures on the sciences connected with the mechanic and useful arts, and in 1955 alone there were eight of our own regular, stated meetings; nine joint meetings with other technical societies; two special meetings sponsored by our membership department under its "Science is Fun" program; the James Mapes Dodge Lectures specifically founded for young people; about 400 additional Institute meetings; and 113 other meetings by many scientific and educational institutions with aims similar to our own. The Institute now has a total of five endowed lectures of which two became a reality this past year: the Charles S. Redding Lectureship and the Philip C. Staples Lecture, each established in honor of a distinguished past president of The Institute.

MUSEUM

The formation of cabinets of models, minerals, machines, materials, and products began with our organization, and although they increased steadily through the years it was not until we had moved into our double-breasted mansion on the Parkway that our dream of a great science museum was realized. During 1955 the most notable addition

to the museum was the Nickelodeon, an authentic replica of a motion picture theatre of the early 1900's. In this theatre, pictures contemporaneous with that era are shown according to a regular schedule. The Nickelodeon was the generous gift of Mr. William Goldman and its opening was marked by a luncheon attended by numerous artists and executives of the motion picture industry.

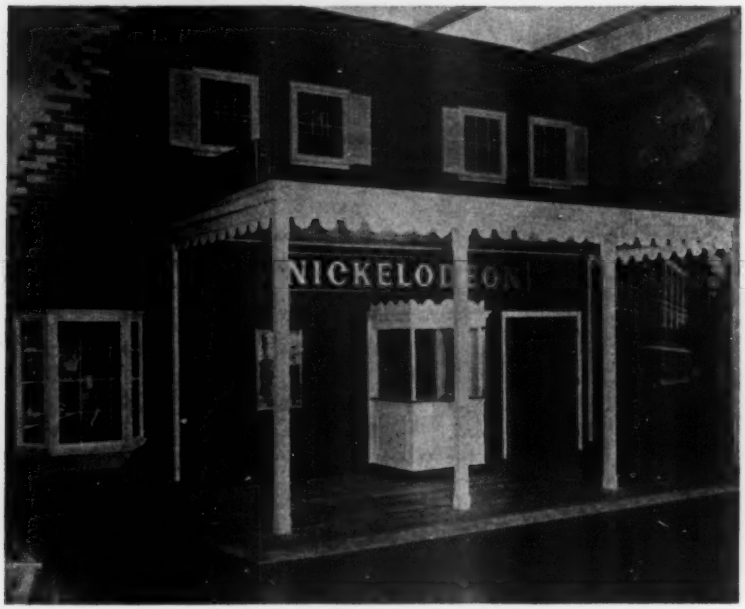


The Franklin Institute

Another important addition, begun and put in operation in 1955 but not yet entirely completed, was an HO-gauge model railroad which will be one of the largest and most completely automatic and technologically up-to-date in the country. Railroaders of all ages from eight to eighty are already fascinated by it. We have to thank the Eastern Model Railroad Manufacturers, as well as the Pennsylvania and Reading Railroad Companies, for their help in establishing and operating this exciting exhibit.

During the year The Institute received many other gifts and loans for use in the Museum too numerous to mention in such a report but for each of which we are indeed grateful.

The work of the Museum's Education Division continued at an increased tempo during 1955. The 7th Annual Delaware Valley Science Fair, co-sponsored by the Philadelphia Inquirer, with 487 exhibits accepted for display, showed not only an increase in number but a very welcome increase in quality. The Institute feels that in this endeavor it is doing something very practicable in guiding young Americans



Exterior view of the Nickelodeon

into the field of science and engineering. Those of our members who attended this Fair must have been extraordinarily impressed by the handiwork of the participants.

The Museum's winter and summer workshops for very young scientists were perhaps accomplishing the same purpose because they both enjoyed almost capacity attendance this past year. The Museum's Education Division, with the co-operation of The American Society for Metals and the Institute of Radio Engineers, also conducted two important forums for this same general purpose, in these cases specifically to explain to secondary school students the career openings that might be found in the metals and electronics

fields. They were so successful that similar programs in other technical fields are being planned.

Young people show no signs of abating their interest in the Museum's activities either alone or in school groups, and efforts must be made to find additional accommodations for them, particularly during vacation and holiday periods. During this past year there were several days

1955 Science Fair Winner, Stephen Dubin of Overbrook High School, receiving award from Mr. John McCabe of Publicker Industries, while Mr. S. Wyman Rolph, President of The Franklin Institute, looks on

when there were over forty busses parked in the neighborhood of The Institute carrying groups of children.

Comparative Museum attendance for 1955 and 1954 was as follows:

	Total Attendance	Free Attendance	Paid Attendance
1955	312,013	84,652	227,361
1954	298,394	76,444	221,950

COMMITTEE ON SCIENCE AND THE ARTS

It has been many years since The Institute has encouraged the mechanic and useful arts by its exhibitions which were famous in their day, but its "premiums," now represented by its annual medal awards,

The 1955 medalists

still continue an important but quiet part of its activities. At our Medal Day celebration last year medals were awarded to the following individuals for their distinguished work:

Elliott Cresson Medal	F. Philip Bowden Cambridge, England
Edward Longstreth Medal	Robert W. Berriman Harrow, England Cecil Waller London, England Richard T. Case Philadelphia, Pa.
Louis E. Levy Medal	David Albert Huffman Cambridge, Mass.
George R. Henderson Medal	Carleton K. Steins Philadelphia, Pa.
John Price Wetherill Medal	Rene A. Higonnet Cambridge, Mass. Louis M. Moyroud Cambridge, Mass. Jacques Y. P. Sejournet Persan, France

Frank P. Brown Medal.....Charles S. Leopold
Philadelphia, Pa.
Stuart Ballantine Medal.....Claude Elwood Shannon
Chatham, New Jersey

LIBRARY

The formation of a library for the use of aspiring young apprentices, mechanics, and manufacturers was a prime and serious object in the organization of The Institute. This library has continued to grow—not only in size but in importance—until it is now one of the great scientific and technical libraries in the country and by far the most important in the area between New York and Washington. During 1955 a welcome grant was received to help the library complete its files of four important organic chemistry periodicals. Also during the year a complete file of *Locomotive Railway and Wagon Review* was secured. At the end of the year the library was receiving 1429 serial publications, an increase of ten during the year. All current complete specifications of United States, British, and Swiss patents continued to be received as well as abstracts from several other countries. In addition we were able to secure microfilm copies of all the original patents in the possession of the U. S. Government from 1790 to 1835; patents lacking in the government's files are being diligently searched for elsewhere with the hope that we will eventually have the finest patent library in existence. The patents from 1835 to 1870 are still lacking. These are available but The Institute does not have funds to get them without help from our friends. We also acquired an excellent microfilm reader which will be increasingly important as the use of microfilm continues to develop.

JOURNAL OF THE FRANKLIN INSTITUTE

The establishment of the JOURNAL OF THE FRANKLIN INSTITUTE was one of those "measures judged expedient" in very early days to encourage the useful arts. In 1955, which was its 130th year of publication, Volumes 259 and 260 appeared and continued the high standards which have characterized its long history.

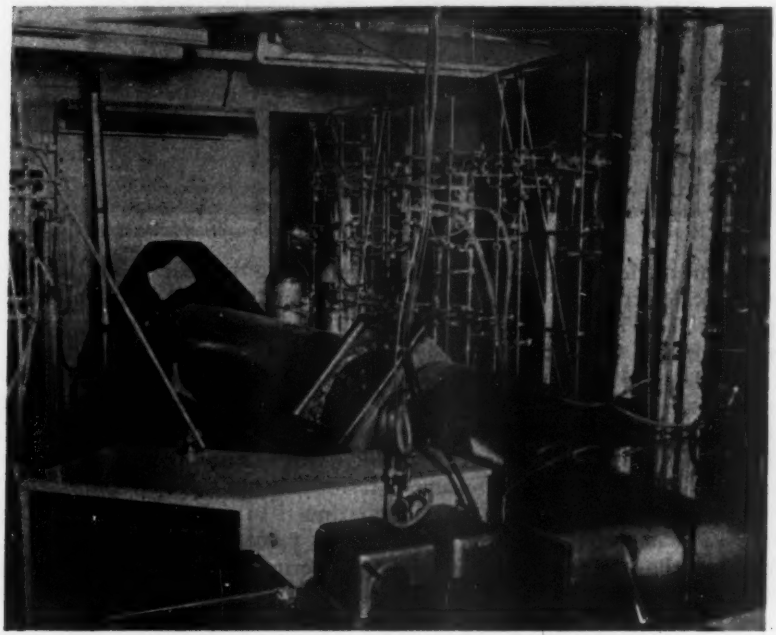
The five scientists from the University of Michigan who jointly wrote "The Folded Tree" which appeared in the July and August issues, will be awarded the Louis E. Levy medal as the paper of especial merit published in the JOURNAL for 1955. The Journal's circulation is limited and its claim to fame is not based on its financial success, but this circulation increased by about 3 per cent in 1955 to approximately 4800, one sixth of which goes to some fifty foreign countries with no less than 130 copies going to Russia alone each month!

RESEARCH LABORATORIES

The Institute's Laboratories for carrying on sponsored research represent its latest "measure judged expedient" for encouraging manufactures and the mechanic and useful arts. This research work continued at a high rate in 1955, although slightly less than for the preceding years, as shown below:

	1955	1954	1953
Revenue from Industrial Projects	$ 661,637	$ 714,569	$ 459,818
Revenue from Government Projects	2,096,888	2,185,047	2,401,465
Total Revenue	$2,758,525	$2,899,616	$2,861,283

There were many accomplishments during 1955 and a few of them must be mentioned. Our work on air pollution gained much recognition, in part because of the papers presented by the staff at meetings of the American Petroleum Institute and the American Chemical Society. The work continues with the construction of a mobile smog analysis unit for experimentation in the Los Angeles area.



Long-path infrared cell used for the study of air pollution

Heart of the floating-zone apparatus for purifying high-melting-point metals

Some nuclear power work which began during the year on a relatively small scale expanded into such a long-range analytical and experimental project that The Institute is firmly entrenched in the nuclear power research field.

Because of the ability we have shown in the field of thermal gradients, transients and stresses and their effects on conventional or unusual materials, we have been invited to write a chapter on "Thermal Stresses" for the Oak Ridge Reactor Handbook. Our nuclear power work may well be one of our most extensive activities within a few years.

Research in solid state physics continued to make progress during the year, one of the most interesting new projects being a large-scale co-operative program for the study of thermoelectric effects. In the field of metallurgy our project for purifying metals to a high degree and determining their properties in that state seems to offer valuable results. Members of our staff published widely in this field of solid state physics.

The Bartol Research Foundation, Swarthmore, Pennsylvania

Research at our Bartol Research Foundation laboratories in Swarthmore also continued steadily during the year with their work in resonance fluorescence of nuclei, neutron scattering experiments, precise measurements of Q-values for nuclear reactions, radioactivity, electrical properties of ionic crystals, bombardment of solid material by high speed electrons, and allied researches. During the year over twenty papers by the Foundation's staff appeared in various scientific journals.

The Biochemical Research Foundation, Newark, Delaware

At the Biochemical Research Foundation for which The Institute assumed the trusteeship in 1935, the basic program related to cancer research in 1955 included the study of acriflavine (which fluoresces under proper illumination) for its tumor growth restraint when in actual contact with tumor cells. Pyridines, slightly altered chemically, were studied for effect on growth of bacteria and tissue cells; as was tumor-host relationship in hatched chicks inoculated in embryo; and changes in rat liver enzyme activity obtained by diet in correlation with senescence and ireoplasia.

PERSONNEL

All the activity which has been recorded above was completely dependent upon The Institute's staff. At the end of the years 1955, 1954, and 1953 this staff (excluding those at Biochemical Research Foundation) numbered 536, 550 and 595, respectively. This trend, which it is hoped will be reversed this year, is a clear indication of the difficulty in obtaining capable scientific personnel for our research activities.

During the year fourteen employees retired after many years of faithful service.

MEMBERSHIP

The Institute's total membership, on which we lean so heavily for support, showed an increase of about two and one half per cent for the year as shown hereunder:

	1955	1954
Honorary	35	38
Sustaining	15	17
Active	3,260	3,174
Associate	2,475	2,383
Student	496	446
Special Library	813	770
	7,094	6,828

One of these members, George R. Hall, was added to our honor roll of those who have held continuous membership for fifty years.

PUBLIC RELATIONS

Through our Public Relations Department we increased our efforts to bring The Institute and all its ramified activities to the attention of the public by means of the press, radio and television. Forty television programs were presented as well as 104 on radio, including "Science, Servant of Man" a weekly feature on the educational FM station WHYY.

Hundreds of inquiries about Franklin, about The Institute, and about all sorts of scientific questions were handled by the Department; and many staff members spoke before various professional and civic groups.

ENDOWMENTS

All these activities of The Institute require money—and they require more money than we now have available. From the annexed income statement it can be seen that our sponsored research activities (with net income of $112,000 after depreciation) supported themselves with something to spare, which must be reserved for the constant demands for additional laboratory equipment so necessary in this day and age. With respect to our other general educational activities with a net loss of $77,000, we do not make ends meet. The situation would be much worse but for the generous support received through the gifts of 380 Friends of Franklin who contributed some $39,000 toward these activities. The moral and material help of this group is of such value to The Institute and its work in the community that we should like to see a substantial growth in both its numbers and its contributions.

As has been pointed out in the past and as will clearly be seen from the financial statements and from the preceding comments, the crying need of The Institute now, as it has been for many years, is for largely increased unrestricted endowment to enable it to carry on the work to which it committed itself when it accepted its new building on the Parkway. We are not unique in this respect; scores or hundreds of similar institutions, each serving its community in its own particular field, must have more income to meet rising costs and expanding demands on their facilities or else be forced to restrict those services they are now performing. It is to be hoped that The Institute itself will continue to be supported in its own field—as it has through more than 130 years—by the people themselves. It is to be hoped that there are those who have faith and belief in our educational and scientific work who will come forward to help us meet this endowment need.

Perhaps there is particular justification for our making this appeal in this 250th Anniversary year of Benjamin Franklin's birth. The 130

years and more of service which The Institute has rendered to this local community of Philadelphia, to the Commonwealth and to the country at large not only in the "promotion of the mechanic arts" but in spreading the teachings of Franklin, its patron saint and the country's great practical philosopher, justify continued support. Surely the vision of the founders will not be forgotten and the work which they so well began will be carried forward by their present-day successors.

FINANCE

The accounts of The Institute have been audited by Messrs. Lybrand, Ross Bros., and Montgomery whose report is available to members for examination in the office of the Treasurer. A summarized comparative balance sheet and statement of general income and expense will be found attached.

Respectfully submitted,
By order of the Board of Managers,
S. WYMAN ROLPH,
President

COMPARATIVE BALANCE SHEET AT DECEMBER 31, 1955 AND DECEMBER 31, 1954

(including Bartol Research Foundation)

Assets

	Dec. 31, 1955	*Dec. 31, 1954*
General Operating Funds		
Cash	$ 424,840	$ 318,915
Amounts receivable from laboratory research contracts	522,157	495,692
Other receivables	63,203	33,577
Inventories	49,243	44,243
Deferred charges	18,692	17,557
Total general operating funds	$ 1,078,135	$ 909,984
Bartol Operating Funds		
Cash	102,179	55,866
Accounts receivable	39,996	42,342
Inventories	14,034	22,799
Deferred charges	1,734	2,066
Total Bartol operating funds	$ 157,943	$ 123,073
Endowment and Other Invested Funds		
Investments at cost (market values $7,537,474 and $6,710,742 respectively)	5,139,955	4,644,937
Uninvested principal cash	124,792	218,020
Advances to general operating funds		51,000
Income cash	27,346	22,733
	$ 5,292,093	$ 4,936,690
DeMonclos Trust Fund:		
Investments at cost	191,214	178,547
Uninvested principal or (overdraft)	51	(109)
Income cash	2,648	2,672
	$ 193,913	$ 181,110
Total endowment funds	$ 5,486,006	$ 5,117,800
General Plant and Property Funds		
Cash	3,554	3,091
Buildings, equipment, fixtures, etc. (less reserves for depreciation of $1,461,317 and $1,326,609 respectively)	3,961,297	4,019,551
Advances to general operating funds	508,566	466,275
Total general plant and property funds	$ 4,473,417	$ 4,468,917
Bartol Plant and Property Funds		
Land, buildings, equipment, fixtures, etc	$ 741,494	$ 729,106
Total assets	$11,936,995	$11,348,880

Liabilities and Funds

	Dec. 31, 1955	*Dec. 31, 1954*
General Operating Funds		
Accounts payable, accrued expenses, etc.	$ 387,617	$ 263,301
Deferred income	41,729	43,236
Advances from plant and property funds	508,566	446,276
Advances from endowment funds		51,000
Provision for redemption of capital stock	9,270	
Capital stock		10,430
Operating fund balance	130,953	95,742
Total general operating funds	$ 1,078,135	$ 909,984
Bartol Operating Funds		
Accounts payable and accrued expenses	21,395	16,842
Operating fund balance	136,548	106,231
Total Bartol operating funds	$ 157,943	$ 123,073
Endowment Funds		
General and restricted endowment funds and funds functioning as endowment including those of the Bartol Research Foundation	5,264,747	4,913,957
Unexpended income	27,346	22,733
Total endowment funds	$ 5,292,093	$ 4,936,690
DeMonclos Trust Fund:		
Principal	191,265	178,438
Undistributed income	2,648	2,672
	$ 193,913	$ 181,110
Total endowment funds	$ 5,486,006	$ 5,117,800
General Plant and Property Funds		
Contributed funds	$ 4,473,417	$ 4,468,917
Bartol Plant and Property Funds		
Plant and property fund balance	$ 741,494	$ 729,106
Total liabilities and funds	$11,936,995	$11,348,880

COMPARATIVE STATEMENT OF GENERAL INCOME AND EXPENSES FOR THE YEARS ENDED DECEMBER 31, 1955 AND 1954

(excluding Bartol Research Foundation)

	1955	1954
Operating Revenue		
Membership dues	$ 64,277	$ 62,717
Museum admissions and other museum income	153,327	150,563
Laboratory research projects	2,758,525	2,899,616
JOURNAL income	21,351	22,915
Other activities	17,044	15,739
Total operating revenue	$ 3,014,524	$ 3,151,550
Operating Costs and Expenses		
Museum	331,495	362,153
Library, net of amounts transferred to other departments	82,546	78,488
Laboratory research projects	2,644,796	2,751,807
JOURNAL expense	33,226	31,712
Administrative and general expenses, net of amounts transferred to other departments	84,122	86,955
Total operating costs and expenses	$ 3,176,185	$ 3,311,115
Operating loss, before other income and charges	$ 161,661	$ 159,565
Other Income		
Income from endowment funds	96,384	98,746
Donations from Friends of Franklin and other gifts	39,440	38,047
Appropriation from Commonwealth of Pennsylvania	46,500	46,500
Other income	22,669	17,043
	$ 204,993	$ 200,336
Net income before other charges	$ 43,332	$ 40,771
Other charges		
Cafeteria expense	6,453	5,957
Interest	1,488	2,349
Miscellaneous	830	423
	$ 8,771	$ 8,729
Excess of income over expenses transferred to Operating Fund Balance	$ 34,561	$ 32,042

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, June 13, 1956.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JUNE 13, 1956.

MR. FRANCIS B. FOLEY in the Chair.

The following reports were presented for final action:

No. 3303: Franklin Medal.

This report recommended the award of The Franklin Medal to Frank Whittle, of Rugby, England, "In recognition of his vision in realizing the limitations of the conventional propeller type of power plant for high speed aircraft, his conception of the combination of the principles of the gas turbine and the rocket, and his pioneering development of the turbo-jet aircraft engine which has revolutionized high speed flight."

No. 3304: Ballantine Medal.

This report recommended the award of the Stuart Ballantine Medal to Kenneth Bullington, of Madison, New Jersey, "In consideration of his advancement of space communications by means of beyond-the-horizon tropospheric wave propagation which resulted from his vision in recognizing the reliability of this means; his ability in planning and executing a broad experimental program; his engineering interpretation of the results which has led to effective design of communication systems employing this means."

No. 3306: Newcomen Medal.

This report recommended the award of the Newcomen Medal to Colin Campbell Mitchell, of Edinburgh, Scotland, "In consideration of his design and development of a steam catapult which makes possible a safer, faster and more powerful method of launching aircraft."

JOHN FRAZER,
Secretary to Committee

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

PIPES, LOUIS A.: Matrix Theory of Skin Effect in Laminations

PENFIELD, ROBERT AND HENRY ZATZKIS: The Relativistic Linear Harmonic Oscillator

BHATTACHARYYA, H. P.: Torque Analysis of the Schrage Commutator Motor

SALZER, HERBERT E.: Osculatory Extrapolation and a New Method for the Numerical Integration of Differential Equations

COULSON, THOMAS: Some Prominent Members of The Franklin Institute. No. 3. Matthias William Baldwin

ATKINSON, CYRIL P. AND L. O. HEFLINGER: Subharmonic and Superharmonic Oscillations of a Bilinear Vibrating System

MOORE, E. F. AND CLAUDE E. SHANNON: Reliable Circuits Using Less Reliable Relays

ROBERSON, R. E. AND D. TATISTCHEFF: The Potential Energy of a Small Rigid Body in the Gravitational Field of an Oblate Spheroid

MEMBERSHIP

ACTIVE MEMBERS ELECTED BY THE BOARD OF MANAGERS

June 20, 1956

ACTIVE FAMILY

Max Cohen
Leon Goldberg
Irving Grossman
J. Renwick Montgomery
F. J. Stokes, Jr.
Francis R. Strawbridge

ACTIVE

W. E. Albright
K. G. Arpajian
Harry D. Attig
B. A. Auerbach
Elvin E. Baker
Harold B. Baxter
W. K. Beard
M. J. Belensky
Raymond H. Blackford
E. H. Breisacher
Edward F. Campion
Paul Chenzoff
Martin Cohen
L. G. Cordier, Jr.
Douglas Y. Cornog
Newton Croll
Paul J. Cupp
George H. Derbyshire
J. M. Devereaux
E. C. Douts
D. A. Dundore
Thomas J. Finley, Jr.
Marian R. Ford
Charles H. Frazier
W. Gilmore, Jr.
Mrs. Joseph K. Gordon
C. S. Hazel
O. B. Holman
E. F. Hubbard
Samuel Katz
John A. Keyes
Walter LaCon
Fred Lieberman
R. A. Linde
B. H. Loper
Charles V. Lynch, Jr.
J. W. Maier
R. C. Matthews
E. D. Maurer
Ernest P. Miklau
H. C. Missimer
John B. Mochel
R. E. Neibel
L. Orlando
R. J. Ott
Gordon O. Perkins
W. C. Powell
Allan M. Rife
H. L. Robbins
H. M. Roberts
W. L. Rushworth
R. A. Sloan
Harold C. Weingartner
John Williams
N. W. Wunder

ACTIVE NON-RESIDENT

Richard S. Gaugler
E. D. Gittens
Basil V. Zolli

NECROLOGY

Joseph S. Clark, Sr. '47
Samuel W. Fernberger '36
Clifford Lewis, Jr. '36
Louis Magaziner '43
James McMullan '52

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor. 586 items have been added the past month.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A.M. until 5 P.M. on Mondays, Tuesdays, Thursdays, and Fridays; 2 P.M. until 10 P.M. on Wednesdays; and from 9 A.M. until Noon on Saturdays.

RECENT ADDITIONS

AERONAUTICS

CARAFOLI, ELIE. Trafflügeltheorie (Inkompressible Flüssigkeiten). 1954.
PARSON, NELS A., JR. Guided Missiles in War and Peace. 1956.

ASTRONOMY

BANERJI, A. C. Recent Advances in Galactic Dynamics. 1942.
SCHRÖDINGER, ERWIN. Expanding Universe. 1956.

ATOMIC ENERGY

MÜNZINGER, FRIEDRICH. Atomkraft. 1955.

BIBLIOGRAPHY

DEITZ, VICTOR R. Bibliography of Solid Adsorbents, 1943 to 1953. 1955.
U. S. BUREAU OF MINES. Bureau of Mines Papers Published in the Technical Press Jan. 1, 1938 to Jan. 1, 1946. n.d.

BIOGRAPHY

INTERNATIONAL BENJAMIN FRANKLIN SOCIETY. The Story of Benjamin Franklin; a Play. 1956.

CHEMISTRY AND CHEMICAL TECHNOLOGY

ADAM, NEIL KENSINGTON. Physical Chemistry. 1956.
ALTIERI, A. M. AND OTHERS. Deinking of Waste Paper. 1956.
BENEDETTI-PICHLER, ANTON ALEXANDER. Essentials of Quantitative Analysis. c1956.
CROCCO, LUIGI AND CHENG, SIN-I. Theory of Combustion Instability in Liquid Propellant Rocket Motors. 1956.
DUNCAN, A. B. F. AND OTHERS. Chemical Applications of Spectroscopy. 1956.
GLOOR, WALTER E. AND KLUG, E. D. Cellulose Data. n.d.

CIVIL ENGINEERING

ANDERSEN, PAUL. Substructure Analysis and Design. Ed. 2. c1956.
NATIONAL RESEARCH COUNCIL. HIGHWAY RESEARCH BOARD. Proceedings. Vol. 34. 1955.

ELECTRICITY AND ELECTRICAL ENGINEERING

BEVITT, WILLIAM DEALTRY. Transistors Handbook. 1956.
BLADEL, J. VAN. Les Applications du Radar. 1955.
CANNING, RICHARD G. Electronic Data Processing for Business and Industry. c1956.
CHAPIN, NED. An Introduction to Automatic Computers. c1955.
HENNEY, KEITH AND OTHERS, ED. Reliability Factors for Ground Electronic Equipment. 1956.
KAPZOW, N. A. Elektrische Vorgänge in Gasen und im Vakuum. 1955.
NATIONAL ELECTRONICS CONFERENCE. Proceedings. Vol. 11. 1955.
NOLL, EDWARD M. Closed-Circuit and Industrial Television. c1956.
Transistors I; a Selection of Papers Describing Research and Development Work at the Radio Corporation of America as it Applies to the Theory, Fabrication, and Application of Transistors. 1956.

ENGINEERING

KUHN, PAUL. Stresses in Aircraft and Shell Structures. 1956.
PHILLIPS, ARIS. Introduction to Plasticity. c1956.
RANZ, WILLIAM E., ED. Thermodynamics and Engineering. 1955.
SEELY, FRED B. AND SMITH, JAMES O. Resistance of Materials. Ed. 4. c1956.
TIMOSHENKO, STEPHEN. Strength of Materials. Pt. 2. Ed. 3. 1956.

GENERAL

CARNEGIE INSTITUTION OF WASHINGTON. Yearbook No. 54. 1955.
CHAPUIS, ALFRED. Histoire de la Boite a Musique. 1955.
TOLMÉ, C. D. Notes on Cuba. 1846.

HOROLOGY

CHAPUIS, ALFRED. De Horologiis in Arte. 1954.

INDUSTRIAL MANAGEMENT

VOAST, JAMES VAN. Increased Production, Reduced Costs; through a Better Understanding of the Machining Process and Control of Materials, Tools and Machines. Vol. 3. c1954.

LAW

NORD, MELVIN. Legal Problems in Engineering. c1956.

MANUFACTURE

STELLE, J. P. AND HARRISON, WM. B. How to be a Gunsmith. c1955.
ZELIKOW, A. I. Hilfsmaschinen der Walzstrassen. Ed. 2. 1954.

MATHEMATICS

DUSCHEK, ADALBERT UND HOCHRAINER, AUGUST. Grundzüge der Tensorrechnung in Analytischer Darstellung. Pt. 2 and 3. 1950, 1955.
DUSCHEK, ADALBERT UND HOCHRAINER, AUGUST. Grundzüge der Tensorrechnung in Analytischer Darstellung. Ed. 3. Pt. 1. 1954.
GRAVES, LAWRENCE M. The Theory of Functions of Real Variables. Ed. 2. 1956.
LAMBERTI, IOHANNIS HENRICI. Opera Mathematica. c1948.
NATANSON, I. P. Konstruktive Funktionentheorie. 1955.
SHANNON, C. E. AND MCCARTHY, J., ED. Automata Studies. 1956.
SHIRTCLIFFE, ROBERT. The Theory and Practice of Gauging, Demonstrated in a Short and Essay Method. 1740.
TERRY, GEORGE S. The Dozen System; an Easier Method of Arithmetic. 1941.
WADE, THOMAS L. AND TAYLOR, HOWARD E. Fundamental Mathematics. 1956.

MECHANICAL ENGINEERING

AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Transactions. Vol. 77. 1955.

METALLURGY

NATIONAL PHYSICAL LABORATORY. Creep and Fracture of Metals at High Temperature. 1956.
WEINBERG, ALVIN M. AND OTHERS. Nuclear Metallurgy. 1955.

MINING ENGINEERING

U. S. BUREAU OF MINES. Minerals Yearbook. Vol. 2. 1953. 1955.
WILSON, VIRGINIA M. Bibliography of Minnesota Mining. 1952.

NUCLEAR ENGINEERING

SCHWEBER, SILVAN S.; BETHE, HANS A. AND HOFFMANN, FREDERIC DE. Mesons and Fields. Vol. 1 and 2. 1955.
UNIVERSITY OF CALIFORNIA. Proceedings; 1955 Conference on Nuclear Engineering. 1955.

PATENTS

U. S. GOVERNMENT PATENTS BOARD. Ceramic, Paper, Rubber, Textile, Wood, and Other Products and Processes; Government-Owned Inventions Available for License. 1954.
U. S. GOVERNMENT PATENTS BOARD. Chemical Products and Processes; Government-Owned Inventions Available for License. 1954.
U. S. GOVERNMENT PATENTS BOARD. Electrical and Electronic Apparatus; Government-Owned Inventions Available for License. 1954.
U. S. GOVERNMENT PATENTS BOARD. Food Products and Processes; Government-Owned Inventions Available for License. 1954.
U. S. GOVERNMENT PATENTS BOARD. Instrumentation; Government-Owned Inventions Available for License. 1954.
U. S. GOVERNMENT PATENTS BOARD. Metal Processes and Apparatus, Machinery, and Transportation Equipment; Government-Owned Inventions Available for License. 1954.
U. S. GOVERNMENT PATENTS BOARD. Ordnance; Government-Owned Inventions Available for License. 1954.
U. S. PATENT OFFICE. Index to Patents. 1955. 1956.

PHOTOGRAPHY

TEXEREAU, JEAN ET VAUCOULEURS, GÉRARD DE. L'Astrophotographie d'Amateur. 1954.
WEISE, HAROLD. Die Kinematographische Kamera. 1955.

PHYSICS

BASHFORTH, FRANCIS. A Mathematical Treatise on the Motion of Projectiles. 1873.
BASHFORTH, FRANCIS. Supplement to a Mathematical Treatise on the Motion of Projectiles. 1881.
BATCHELOR, GEORGE KEITH AND DAVIES, R. M., ED. Surveys in Mechanics. 1956.
BOUCHARLAT, JOSEPH LOUIS. Élémens de Mécanique. 1815.
CAMPBELL, I. E., ED. High-temperature Technology. 1956.
CARNOT, L. N. M. Principles Fondamentaux de l'Équilibre et du Mouvement. 1803.
CHARLES, VICTORIN. Problémes Élémentaires de Physique Atomique et de Chimie Nucléaire. 1955.
HOFFMAN, G. Einführung in die Hydraulik. 1953.
INTERNATIONAL UNION OF THEORETICAL AND APPLIED MECHANICS AND INTERNATIONAL ASTRONOMICAL UNION. Gas Dynamics of Cosmic Clouds. 1955.
JEFFREYS, HAROLD AND JEFFREYS, BERTHA SWIRLES. Methods of Mathematical Physics. Ed. 3. 1956.
KUDRJAWZEW, B. B. Anwendung von Ultraschallverfahren bei Physiklisch-Chemischen Untersuchungen. 1955.
PEIERLS, RUDOLF ERNST. The Laws of Nature. 1956.
SPITZER, LYMAN, JR. Physics of Fully Ionized Gases. 1956.
VENTUROLI, GIUSEPPE. Elements of Practical Mechanics. 1823.
VENTUROLI, GIUSEPPE. Elements of the Theory of Mechanics. 1822.

RESEARCH

Industrial Research Laboratories of the United States. Ed. 10. 1956.

SCIENCE

FORBES, ROBERT J. Studies in Ancient Technology. Vol. 1-3. 1955.
IRVINE, JAMES COLQUHOUN. The Aim and the End. 1956.

SUGAR

GREAT BRITAIN (GEORGE III). A Bill for Opening and Establishing Certain Ports in the Island of Jamaica and Dominica, for the more Free Importation and Exportation of Certain Goods and Mechandizes. 1766.

STATISTICS

LINDLEY, D. V. AND MILLER, J. C. P. Cambridge Elementary Statistical Tables. 1953.

WOOD

U. S. PULP PRODUCERS ASSOCIATION, INC. Wood Pulp Statistics. Ed. 20. 1955.

PUBLICATIONS RECEIVED

THE THEORY OF SOUND, Volume 1, by Lord Rayleigh. Reissue of unabridged second revised edition with an historical introduction by Robert B. Lindsay. 480 pages, $5\frac{1}{4} \times 8$ in. New York, Dover Publications, 1956. Price, $1.95 (paper).

THE THEORY OF SOUND, Volume 2, by Lord Rayleigh. Reissue of unabridged second revised edition with an historical introduction by Robert B. Lindsay. 504 pages, $5\frac{1}{4} \times 8$ in. New York, Dover Publications, Inc., 1956. Price, $1.95 (paper).

FAMOUS PROBLEMS OF ELEMENTARY GEOMETRY, by Felix Klein. 'Reissue of second edition revised and enlarged with notes by Raymond Clare Archibald. 92 pages, $5\frac{1}{4} \times 8$ in. New York, Dover Publications, Inc., 1956. Price: $1.00 (paper); $1.50 (cloth).

THEORY OF GROUPS OF FINITE ORDER, by Robert D. Carmichael. Unabridged and unaltered republication of the first edition. 447 pages, $5\frac{1}{4} \times 8$ in. New York, Dover Publications, Inc., 1956. Price: $2.00 (paper); $3.95 (cloth).

THE THIRTEEN BOOKS OF EUCLID'S ELEMENTS. Translated with introduction and commentary by Sir Thomas L. Heath, reissue of second edition, unabridged, in three volumes. 432, 546 and 436 pages, respectively, $5\frac{1}{4} \times 8$ in. New York, Dover Publications, Inc., 1956. Price: $1.95 each volume (paper); $5.85 the set of three volumes (paper).

TO MEMBERS AND THOSE WHO KNOW THE FRANKLIN INSTITUTE

All of us associated with The Franklin Institute are gratified by the support given by its benefactors in the past. Without their generosity our privately endowed Institute would have been unable to serve industry, the professions, and the public as it has and should.

There is still a continuing and pressing need of contributions and bequests —both for general and specific endowment, and of income to be judiciously used. Your response will be most earnestly appreciated.

Checks should be made payable to The Franklin Institute, and sent to The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia 3, Pennsylvania.

Where property is transferred, title should be in the name of The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

We shall be glad to supply any additional information regarding gifts and memorials. Please write to the above address, attention of the Endowment Department.

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

NICOL H. SMITH, DIRECTOR

LOW-TEMPERATURE DUCTILITY OF IRON

BY

R. L. SMITH AND J. L. RUTHERFORD

A classical metallurgical problem for many years has been that of the brittle behavior of iron and low alloy iron base materials at low temperatures. The seriousness of the problem has been dramatically emphasized by the catastrophic failure of merchant vessels during World War II. In some cases, these failures involved the complete breaking in two of welded tankers and cargo carriers. Such failures have not been restricted to ships but have occurred in many instances where ferritic steels have been used at low temperatures.

The research stimulated by such failures has resulted in a considerable wealth of knowledge concerning the brittle behavior of steels. For instance, it is known that such materials can undergo a considerable deformation in torsion at low temperatures, yet show complete brittleness upon impact. A coarse pearlitic structure may have zero ductility at some low temperature, yet the same composition steel with a tempered martensitic structure can have a high ductility at the same temperature. A coarse-grained steel will show much less ductility at low temperatures than a fine-grained steel. Minor alloying additions can increase the low-temperature ductility considerably. Low-temperature tests accentuate these differences. Such knowledge has not, however, led to the basic reason of why iron is brittle at low temperatures.

Seigle and Brick[1] pointed out that all unalloyed body-centered cubic metals are less ductile at low temperatures. This is in contrast to face-centered cubic metals which retain their ductility down to liquid helium temperatures. The question then arises to whether the body-centered lattice is directly responsible for the brittle behavior.

Iron is difficult to prepare in a state of purity much higher than 99.9% Fe so that practically nothing is known of the mechanical properties of high purity material. Research in the Solid State Physics Division of the Laboratories has been directed toward the preparation of high-purity iron by zone melting with a floating zone technique.[2] One of the primary purposes of this research is to determine how trace impurities affect the physical and mechanical properties of iron.

Zone-melted iron tested in tension at 4.2° K. has shown ductile fractures with an 80 to 90 per cent reduction of area. Two explanations

[1] L. SEIGLE AND R. M. BRICK, *Trans. ASM*, Vol. 40, 813 p. (1954).

[2] R. L. SMITH AND J. L. RUTHERFORD, paper presented at AIME Reactive Metals Conference, Buffalo, N. Y., March 19, 1956.

for this high ductility present themselves immediately: high-purity body-centered cubic materials are ductile at low temperatures but are much more sensitive to trace impurities than face-centered cubic materials; body-centered cubic materials require at least a certain amount of a given trace element to impart ductility and the nearly complete absence of others that might cause brittleness. The second possibility should be considered very seriously since it is well known that small amounts of oxygen seriously impair low-temperature ductility of iron. Carbon steels can be made to show some ductility at liquid helium temperatures whereas, until the present results were obtained, the best pure irons tested have shown no ductility at this low temperature. Does this mean that a certain amount of carbon and no oxygen is necessary for ductility to be retained or does it mean that it is immaterial whether carbon is present as long as there is no oxygen?

Such questions at first appear to be easy to answer, but when analytical methods of determining trace elements are examined, the results are disappointing. It must be kept in mind that only a few parts per million of some elements can sometimes cause drastic changes in the properties of materials. There is no way to detect and identify with certainty many of these trace elements.

Before the ductility problem is solved, many other ideas will have to be examined. There are more subtle possible explanations. For instance, it can be shown that substitutional solute atoms will be expected to anchor only edge dislocations in face-centered cubic metals, whereas both edge and screw dislocations can be anchored by interstitial atoms in body-centered cubic metals. Solute atoms which distort the lattice equally in all directions can interact with a hydrostatic stress field, but, in order to interact with a shear stress, the distortion must not be spherically symmetrical. The tetragonal distortion that carbon and nitrogen produce in iron is a nonspherical distortion, but according to Cottrell[3] there are no known principles which would lead one to expect nonspherical distortions around solute atoms in a face-centered cubic lattice. A row of interstitial carbon atoms in iron exerts a strong interaction extending only over a short distance, a situation that is favorable for the introduction of pronounced thermal effects such as the decrease in total strain with decrease in temperature that is observed in ferrites.

Regardless of the answer as to why the ductile-to-brittle transition occurs in iron, the important point is that the liquid helium tests at FIL have shown that the tensile ductility of iron can be retained at 4.2° K. The process of finding out why is made much easier since it can now be narrowed down progressively.

[3] A. H. COTTRELL, "Symposium on the Plastic Deformation of Crystalline Solids," May 1950, Joint Sponsorship of Carnegie Institute of Technology and the Department of the Navy, Office of Naval Research.

NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, DIRECTOR

LIQUID FLOW MEASUREMENT

Water is so common that we do not, in ordinary times, think of the quantity we consume. Thought upon the subject usually comes when the periodical water bill arrives and we become acutely conscious of the huge volume we have consumed, and the fact that there is a meter in the house measuring the flow of water. Water is not the only fluid that is measured by meters.

Fluids may be liquids, like water and oil (which are incompressible), or gaseous, like steam and illuminating gas (which are compressible). Thus a very wide field has to be covered, ranging from the steam that goes hurtling at dizzy speed through a steam turbine, to the slow moving molten metal of a blast furnace, or molasses in a candy factory. Most of these at some point or other may need to be measured and, since most liquids are used at points distant from the place where they are stored, steps must be taken to regulate their flow.

Meters are constructed to perform different functions. For example, the meter used to indicate the volume of water consumed in a dwelling would not serve to measure the flow of water from the reservoir supplying many thousands of homes and industrial plants; nor would it answer in determining whether there was a leakage in an industrial plant, like a paper-mill, where the consumption is enormous.

The Romans were the first to construct a method of conveying a water supply over a long distance. The value of the water was recognized, and an effort was made to measure its use by individuals. However, the Romans did not proceed very far in this direction, since their method of measurement was restricted to varying the dimensions of the straight narrow pipe that fed the individual dwelling. Crude as it was, this method was still in use through the sixteenth century.

The domestic water meter did not appear in this country until the time of the Civil War. Previously, people had paid a flat rate for their water supply without knowing how much they consumed. The time had arrived when every city was put to great expense through the necessity of installing a water supply system, and water became a valuable commodity that required to be paid for in proportion to the volume consumed. The introduction of a metering system encountered a great deal of opposition because of the unsatisfactory meters that were available. Winter presented appalling problems because most meters froze. As soon as the prejudices were overcome and meters

were accepted as necessities, ingenious men devised a number of types to meet varied requirements, so that we how have a variety of meters that are both simple and efficient.

In an industrial plant, the engineer who understands the use of his meter charts can learn a lot about the operation of his equipment and the quality of his fuel, for these meters reveal more than the amount of water that flows through them. When used on boiler-feed-water lines a meter will betray sources of waste. Primarily, they measure accurately the amount of water evaporated in the boiler. Since fuel is bought in measured quantity, the engineer can calculate the rate of evaporation. The meter thus indicates what is a dollar's worth of heat. If a steam leak should occur, more water must be evaporated to develop the requisite power, and the meter instantly records the increase in the water supply. If an air leak should occur, more fuel will have to be consumed to obtain the evaporation of a given quantity of water.

Since practically all of the meters installed in industrial plants incorporate a recording system that permits a record of performance to be kept, reference to these charts permits the engineer to check current performance and to make comparisons with previous performances. One might almost say that a meter, when intelligently used, is a kind of X-ray apparatus which tells the engineer what is going on in the metal and brick casing of his boiler plant.

Recent changes in the Museum have caused the removal of the Liquid Flow Measurement exhibit to the Physics Section as a matter of convenience. But while this shows various methods of measuring large and small volumes of flowing water, attention should be given to the variety of meters in the cab of Locomotive 60,000, and on the instrument of an airplane in other parts of the building. Here will be found meters for measuring water flow and air pressure.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION
ELLICE McDONALD, M.D., FOUNDER WILLIAM G. BATT, D.Sc., DIRECTOR

THE OCCURRENCE OF DUMBBELL-SHAPED NUCLEI

BY
IRVING GALINSKY

The presence in the cell of a nucleus which differs in shape from that found normally has long been a matter of interest. The dumbbell-shaped nucleus is the most frequently observed of these abnormalities and has been found both in normal tissues and more frequently in tumor tissues. When tissues, normal or cancerous, are treated with mitotic poisons there is always an increase in the number of dumbbell-shaped nuclei.

It is not surprising that many of the earlier workers in trying to explain nuclear division, were led astray by such dumbbell-shaped nuclei and adhered to the theory that the nuclei were dividing amitotically by simply constricting. However, it is now generally accepted that mitosis is the basic form of nuclear division and that these dumbbell-shaped nuclei are the result of deviations from the normal in mitosis.

There are different explanations as to how dumbbell-shaped nuclei can be formed and these are discussed here.

Chromosome bridges. Under certain conditions, such as chemical treatment (1), radiation (2), cancerous growth (3), the chromosomes exhibit stickiness and may stick together along their whole length or only part of their length. As the daughter chromosomes move to opposite poles, their stickiness produces chromosome bridges. Chromosome bridges may also be formed from lagging chromosomes which fail to reach the poles before telophase occurs (Fig. 1). A third type of bridge is due to dicentric chromosomes produced by translocation (4).

Cell division may or may not occur. If it does not, a dumbbell-shaped nucleus is formed (Fig. 2). If cell division does occur the bridge may be severed and nuclei with fingerlike projections result (Fig. 3). The series involving chromatin bridges in the formation of dumbbell-shaped nuclei has been designated as pseudoamitosis and has been correctly understood for some time.

Nuclear fusion. Pfuhl (reported by Wilson and Leduc (5)) considered all "amitotic" figures to be either the two nuclei of a binucleate cell in the process of fusion, or two nuclei that had previously fused, in the process of separating again. Brues and Jackson (6) found, in addition to multinucleate cells, cells with single ameboid-shaped nuclei which they suggested may represent early fusion of micronuclei to form

a single resting nucleus. While some fusion may occur, it is difficult to explain why many nuclei of binucleate cells may lie in close proximity without any fusion occurring. Also, a rather large number of nuclei would have to be in the process of fusing or separating.

Failure of the spindle. The achromatic spindle is sensitive to a great

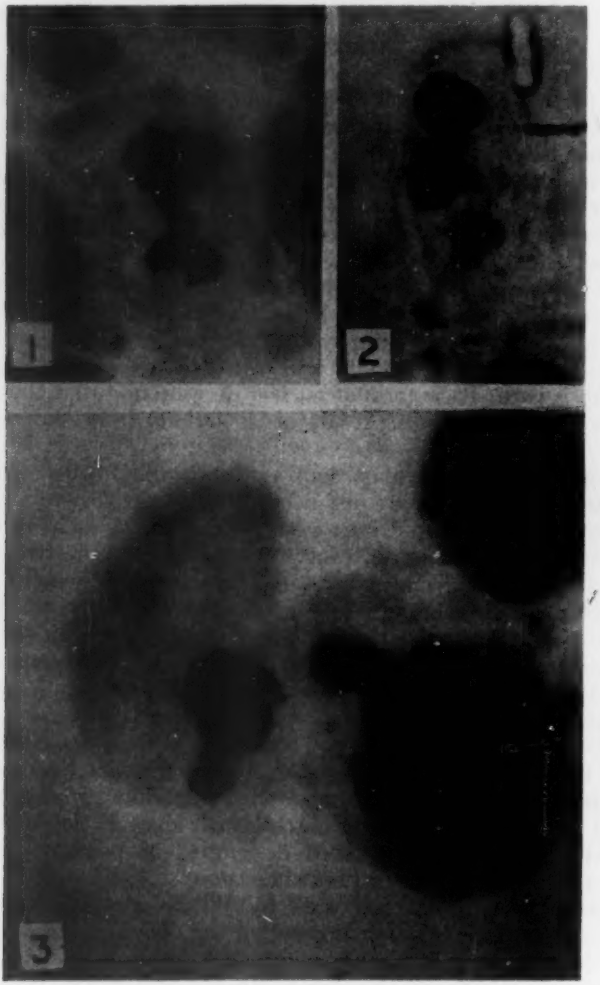


FIG. 1. Bridges formed by lagging chromosomes between two chromosome groups.
FIG. 2. Dumbbell-shaped nucleus resulting from chromosome bridges.
FIG. 3. Nuclei with fingerlike projections resulting from breakage of chromosome bridge during cell division.

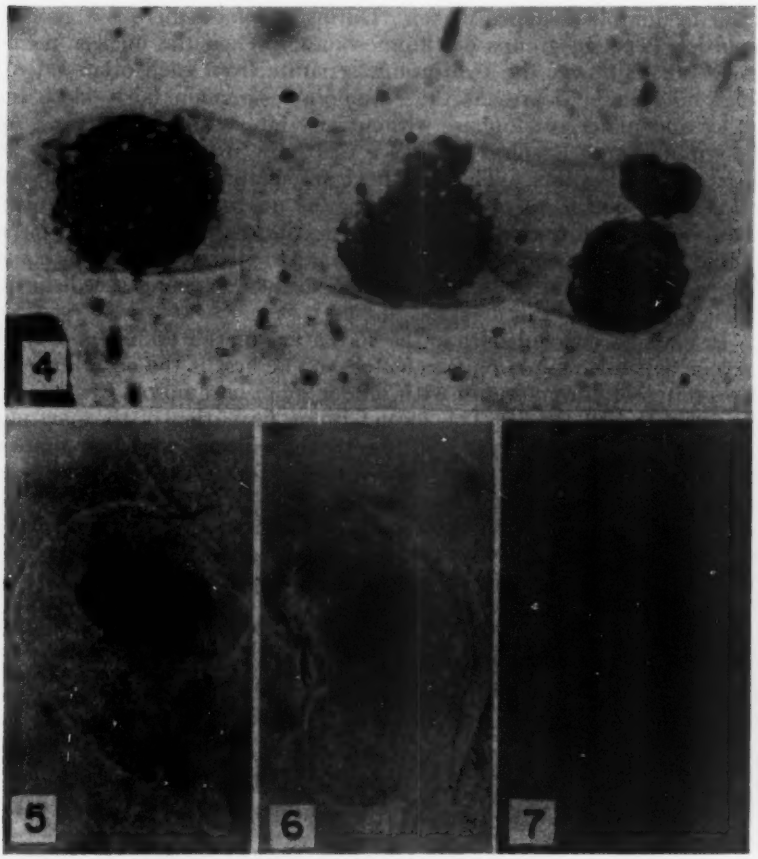


FIG. 4. Three cells showing a normal nucleus, a "budded" nucleus, and a dumbbell-shaped nucleus.

FIG. 5. Two groups of chromosomes in close proximity due to failure of spindle.

FIG. 6. Dumbbell-shaped nucleus resulting from two groups of chromosomes in close proximity due to failure of spindle.

FIG. 7. Dumbbell-shaped nucleus formed by two chromosome groups not in close proximity.

variety of disturbances by a large number of agents both physical and chemical. Since more cases of spindle disturbances have been reported than of chromosome bridges or nuclear fusions, it follows that this phenomenon may account for most of the dumbbell-shaped nuclei.

Failure of the spindle at anaphase may result in two separate nuclei or a single, dumbbell-shaped nucleus depending upon the proximity of the two chromosome groups. Spindle failure at prophase may also

result in dumbbell-shaped nuclei. During prophase there is a type of repulsion between groups of chromosomes. When the nuclear membrane breaks down, the two groups separate from each other (**7, 8**). Since no spindle is present the chromosomes remain fairly close together and undergo telophase without any intervening anaphase. As the chromosomes unspiral there is a tendency for them to overlap at their proximal points. The new nuclear membrane which is formed follows the outline of the chromosomes, no matter how irregular. Dumbbell-shaped nuclei can vary in the thickness and length of the handle portion depending upon the distance between the chromosome groups and the number of chromosome strands spanning the distance (Figs. 4, 5, 6, 7).

It may be concluded that the formation of the dumbbell-shaped nucleus depends mainly on two factors. The first is the occurrence of two groups of chromosomes with one or more chromosomes spanning the gap between them. The second is the formation of the new nuclear membrane around the outline of the chromosomes, no matter how irregular it may be. It has been shown that these two conditions can occur as the result of a number of different mitotic disturbances. Other explanations which involve nuclear constriction or fusion have not been substantiated to any great degree and cannot account for the formation of the majority of dumbbell-shaped nuclei.

REFERENCES

(1) P. C. KOLLER, *J. Nat. Cancer Inst.*, **15**, 1237 (1955).
(2) P. C. KOLLER AND A. CASARINI, *Brit. J. Cancer*, **6**, 173 (1952).
(3) S. MAKINO, *Chromosoma*, **4**, 649 (1952).
(4) J. W. WILSON AND E. H. LEDUC, *Am. J. Anat.*, **86**, 51 (1950).
(5) J. W. WILSON AND E. H. LEDUC, *Am. J. Anat.*, **82**, 353 (1948).
(6) A. M. BRUES AND E. B. JACKSON, *Am. J. Cancer*, **30**, 504 (1937).
(7) I. GALINSKY, *J. Heredity*, **40**, 288 (1949).
(8) G. B. WILSON, M. E. HAWTHORNE AND T. M. TSOU, *J. Heredity*, **42**, 183 (1951).

BOOK REVIEWS

MASS TRANSFER OPERATIONS, by Robert E. Treybal. 666 pages, diagrams, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1955. Price, $9.50.

Mass transfer is an important part of chemical engineering. There is hardly any physical or chemical operation which does not include at one stage a process of mass transfer. Thus, mass transfer operations occupy a central part of any chemical engineering curricula. The purpose of the book under review is to provide a text for teaching purposes, together with the possibility of giving to the student an appreciation of the modern technical literature on the subject. It is therefore to be expected that throughout the book the theoretical background is stressed, but also a good deal of discussion is devoted to equipment design, operation and application.

In the introduction the author discusses diffusional operations in general. Some design principles are also pointed out. In the second chapter the author presents the basic concepts and mathematical treatment for the molecular diffusion in gases, liquids, momentum and heat transfer in laminar flow. The case of turbulent flow follows in chapter 3. Diffusion in solids is discussed in the following chapter. Interphase mass transfer processes are presented in chapter 5, for different types of phases and processes. These first 5 chapters of this volume make up the general background for the discussion on several types of unit operations, which follows in part II.

Equipment and physical characteristics of gas-liquid separations are presented in chapter 6 while humidification operations are taken up in chapter 7. Gas absorption is discussed in a subsequent chapter. For each operation a discussion on fields of application, types of equipment used, methods of design and design data are given. Moreover, a large amount of problems are provided at the end of each chapter.

The presentation of distillation follows from considerations of vapor-liquid equilibria, the effect of pressure and temperature and departure from ideality. The treatment is thorough and up to date. In chapter 10, liquid or solvent extraction is considered and different cases analyzed.

The last section of the book is devoted to solid-fluid operations and to less conventional processes. Adsorption of gases, vapors and liquids, different kinds of adsorptions and adsorption isothermus are considered in chapter 11, together with ion exchange. The steady state and unsteady state operations are discussed.

Chapters 12 and 13 deal with drying and leaching operations. Finally, dyalysis and electrodyalysis, different kinds of gas separation (diffusion and thermal diffusion) are considered in the last chapter. Throughout the book the basic features common to all mass transfer operations are emphasized. This gives a well integrated treatment of all the processes discussed. In conclusion, this volume is an useful addition to the rapidly growing library of chemical engineering volumes.

G. PARRAVANO

PRINCIPLES OF HELICOPTER ENGINEERING, by Jacob Shapiro. 433 pages, diagrams, 6 × 9 in. New York, McGraw-Hill Book Co., Inc.; London, Temple Press; 1955. Price, $12.50.

There has long been a need for a "design-oriented" book on the many practical design aspects of the helicopter. The author, one of England's most experienced project engineers, has succeeded admirably in presenting the foundations and conditions of the basic theory, along with their applicability. To the best knowledge of this reviewer, no other text exists today which has so clearly and concisely correlated the wealth of basic theoretical data and the many recent advances in the various aspects of the helicopter.

The author recommends that, "Readers for whom this book is a first introduction to

helicopter principles are advised to pursue the following plan; start with the first three sections of Chapter I, on the foundations of the aerodynamics of rotors. Chapter 5 on the requirements and types of helicopters should follow, and thereafter Chapter 2, on the performance of helicopters. After this first round the details of helicopter structures and mechanisms should be studied in Chapter 4. The theoretical development of Chapters 1 (second part), 3 and 4, dealing with aerodynamics, rotor dynamics, and mechanics of flight, can now be usefully studied."

Chronologically and specifically, Chapter 1, Rotating Wings in Steady Flight, includes sections on the actuator disc, the real rotor, rotor performance, aerodynamic problems, and rotor analysis. Chapter 2, Performance of Helicopters, discusses performance of rotorcraft elements, performance of power units, and application of performance analysis. Chapter 3, Dynamics of the Rotor, is concerned with fundamentals of blade dynamics, motion of rigid blades, loads, rotor forces and derivatives, rotor systems, and rotor vibration.

Chapter 4, Mechanics of Helicopter Flight, covers the principles of helicopter control, the stability and control of single-rotor helicopters with a hinged or with modified rotor systems, and the stability and control of multi-rotor helicopters. Chapter 5, Helicopter Projects, presents sections on design requirements, quality criteria, and classification of configurations. Chapter 6 is rather general and contains many interesting and detailed discussions and illustrations of the helicopters' components and assemblies.

This book is a welcome addition to the library of the aeronautical sciences. It fills a big void in the ever expanding field of helicopter engineering. It is well written, practical, timely, and well illustrated.

S. M. BERKOWITZ

CHEMICAL ENGINEERING, VOLUME II, UNIT OPERATIONS, by J. M. Coulson and J. F. Richardson. 975 pages, illustrations, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1955. Price, $9.00.

In the first volume of this series a discussion of fluid dynamics and heat and mass transfer was presented. The applications of the principles derived are the subject of the second volume of this series. This book, therefore, is concerned only with those operations of chemical engineering which are physical in nature. The most important feature of the book under review lies in the rigorous and fundamental approach used.

This is a very welcome trend and it clearly differentiates this book from other publications on the same subject.

The first section of the volume treats fluid flow, granular beds, and packed columns. Filtration and centrifugation are discussed in the following chapters. In each case the basic theory is presented first, followed by its application to different practical conditions. There is also some discussion on basic equipment, illustrated with very clear photographs. Some of the most important aspects of both filtration and centrifugation are illustrated also by means of problems whose solution is developed at the end of each chapter.

The next section deals with systems involving the relative motion between fluids and particles. Thus, problems concerned with the drag on particles of different shapes due to fluid flow, with the motion of bubbles, drops and particles in a fluid are discussed. Subsequently, the fundamental information is applied to sedimentation, fluidization and conveying. Emphasis is put on the hydrodynamic characteristics of each system discussed. Topics presented here include: heat transfer in fluidized systems, mass transfer in fixed and fluidized beds, application of fluidized solids technique to petroleum cracking, pneumatic and hydraulic conveying, mechanism of suspension of particles, energy for conveying, pressure drops and solid velocities. This section is concluded with a chapter on gas cleaning.

The third section of this book presents the applications of mass transfer to chemical engineering operations. Leaching, distillation, gas absorption and liquid-liquid extraction are discussed. In the next section, the operations of evaporation, crystallization and drying are discussed. New types of evaporators and some industrial installations are treated. In all cases the presentation of the subject matter starts with the basic features of the processes involved.

In the last section of this volume, the operations of size reduction and classification of solids and mixing are discussed. Some of the topics presented here are: mechanism of size reduction, energy requirement, particle size distribution, equipment, particle separators, rate of mixing, power consumption of mixers, degree and rate of mixing, etc. The book ends with a selection of problems to be worked out by the reader.

The fundamental approach stressed throughout, the clarity of presentation and selection of topics, the wealth of data, graphs and literature reference, make this book an outstanding addition to the library of a chemical engineer. It is, therefore, a book to be highly recommended. G. PARRAVANO

INSTRUMENT ENGINEERING, VOLUME III, PART I, MEASUREMENT SYSTEMS, by C. S. Draper, W. McKay and S. Lees. 879 pages, charts and diagrams, 8½ × 11½ in. New York, McGraw-Hill Book Co., Inc., 1955. Price, $17.50.

As long as fifteen years ago, the reviewer was priviledged to study the instrument analysis course, upon which this book is based, under MIT's Professor Draper. One of the other authors, Walter McKay, was also active in the Aeronautical Laboratories at the same time and contributed largely to the instrument studies then going on. It was at this time rumored that a book was about to be published on the methods which Professor Draper had formalized, and it is gratifying to see that this has now been done.

Such a complex subject deserves a technically comprehensive treatment. Consequently, the proportions of this volume, which deals so thoroughly with measurement systems, are on a large scale. Included are generalized characteristics of currently-used transducers as well as the theoretical response expressions associated with their system applications. No effort has been spared to make this work as profound as could conceivably be required by the practical instrument problem.

Much of the work referred to in this volume is an outgrowth of aeronautical instrumentation studies, and in this field the authors have few equals. Consultant to the Sperry Gyroscope Company for many years, Stark Draper is perhaps the leading authority on gyroscopic systems and instruments. On the other hand, his formal training was in electrical engineering, so that special interest has been directed toward devices which combine electrical and mechanical principles.

In addition to the familiar term, transducer, these authors have introduced an interesting new word, "coducer." This word distinguishes a device in which the input acts jointly with an auxiliary source of power to produce the output. In general the input to the coducer controls the output, and the power source has primarily the influence of supplying energy.

Of great assistance in interpreting the many complex analytical expressions are graphical plots of the functions. With these curves it is often possible to make credible estimates of instrument response without resorting to computation.

This work, in view of its extent and thoroughness, is without doubt the most exhaustive treatise on instrument analysis ever prepared. Some slight obsolescence may occur at a future time as new types of transducers and instrument techniques develop, but the basic principles covered will still pertain to most of these. Meanwhile, this excellent work must be considered a primary source of reference in the field of instrument engineering. C. W. HARGENS

CURRENT TOPICS

Radio Telescope to Measure Sun's Atmosphere.—A new type of radio telescope will soon begin the task of exploring the sun's turbulent atmosphere. The Air Research and Development Command's Air Force Office of Scientific Research has financed the construction of this new apparatus, after conception of the idea by Stanford University.

Called a microwave spectroheliograph, the device will carry on its explorations from an observation point on the Stanford University campus. It consists of 32 parabolic aluminum antennas, known as "dishes," which will be aligned in two rows to form a huge cross occupying a level, two-acre meadow.

Under the direction of Professor Ronald N. Bracewell of Stanford's Radio Propagation Laboratory the device will pick-up solar microwave radiations in the 3000 megacycle region.

As the dish antennas scan the sun's surface in the same way a television camera scans its subject, the photograph produced shows the "chromosphere"—a hitherto mysterious billowing layer of incandescence, rising to heights of 6000 miles above the sun's surface.

Although discovered many years ago at the time of solar eclipses, little is known about the chromosphere. The development of radio astronomy in the postwar era has renewed efforts to unveil its secrets. It is believed to have some connection with sunspots, which in turn are related to magnetic storms which interrupt radio communications.

The 32 antennas will look straight at the sun, scanning its surface in unison, and following automatically as it crosses the sky. A photograph of the entire solar orb will be completed in about two hours. Clouds will not affect antenna efficiency.

Dr. Bracewell has recently served as a research officer with the Commonwealth Scientific and Industrial Research Organization at Sydney, Australia, a world center of radio astronomy research.

A primary accomplishment will be the scanning of solar regions as small as three-thousandths of one square degree, a definition finer than ever before achieved in radio astronomy or in radar.

Stratospheric TV.—Television moved into the supersonic age with the recent announcement by Philco Corporation that it has developed an airborne TV system which may be used in jet aircraft reconnaissance by the U. S. Air Force. Developed at Philco's Government & Industrial Division for the Aerial Reconnaissance Laboratory at Wright Air Development Center, the new airborne TV system will provide ground control points with an active picture of troop movements or terrain. It now is possible to transmit a TV picture, not only from near ground level, but from the stratosphere, beyond reach of antiaircraft gun fire. The scope of such a reconnaissance system is almost unlimited.

Unlike those systems which have been used commercially to relay TV signals from one ground point to another, via a slow-circling plane, the new airborne reconnaissance system is a complete, self-contained, broadcasting

station. It is so compact that it may be carried in single-seat aircraft. Philco has many years of research and development experience on this type of equipment.

To cover a wide area, two unmanned, studio-quality TV cameras are used in the plane. Signals from the plane are transmitted to the ground control point where they are picked up by a receiver. There, the picture may be instantaneously photographed on 35-mm. film which can be processed in less than a minute. Immediately, the picture may be projected on theater-size screens at the control point, or relayed to other locations. Also, pickups from slower-moving aircraft may be observed, live, on standard fine-line monitors.

Philco has overcome the inherent difficulties of obtaining a clear, sharp picture from aircraft traveling at supersonic speeds by the development of unique transmitter circuitry and the method of transmitting a high-quality picture. The picture obtained is as good as, or better than, commercial TV reception. It is now possible to slow, or stop, TV pictures taken at high speeds without a blur of ground movement.

Data, such as time and position, may be automatically printed on the film. In addition to on-the-spot coverage, a permanent reconnaissance record may now be maintained.

High-Temperature Lubricants.—A General Electric chemist announced recently that laboratories are "on the doorstep" of finding high-temperature aircraft lubricants that will operate between 1000 and 2000° F.—more than three times hotter than existing lubricants.

Dr. Donald F. Wilcock of Schenectady, N. Y., said the problem of cracking the thermal barrier in lubrication "is perhaps the most critical bottleneck in developing planes that will make present speed records obsolete."

"We have metals that will function up to 2000° (F.) but we've never had a fluid lubricant that would keep pace," Dr. Wilcock said. "Today the upper limit is around 500° in aircraft hydraulic systems and around 350 in bearings. Silicone fluids can take us to 600°, at the most 700."

The new compounds, he added, will flow at red heat and will open up "entire new horizons in aircraft engine design." They will apply to both hydraulic systems and bearing systems.

"Up to the present time, we have been handicapped by the temperature limits of silicone oils—between 600 and 700° F.," Dr. Wilcock said.

"But we are now opening new vistas in the lubrication field—compounds that potentially will boil in the range of 1000 to 2000 degrees Fahrenheit. Our laboratories are on the doorstep of an extremely significant breakthrough in the thermal barrier.

"Of course, further development will be needed, but I see no reason why we cannot reach these temperatures in the near future."

The speaker said the characteristics of such super-compounds pose a new problem for chemists and engineers—freezing too quickly.

"Some of these compounds have such a fantastically high boiling point that they will actually freeze at temperatures around 400 degrees. This is all the more incredible when you consider that this is in the range where some present lubricants boil."

Then he added:

"The challenge to the structural organic chemist is to design these stable high-boiling molecules so that they will be fluid at lower temperatures, and so that they will have the 'oiliness' characteristic necessary for many vital applications."

New Textile Filament.—Culminating an extensive research program in the field of crimpable fibers, American Viscose has announced a new textile filament which will have new and interesting market possibilities. As described at the annual meeting of stockholders, the new product is handled as a regular fiber but it develops a permanent crimp when wet with water. This characteristic has long been desired by the textile industry and the corporation believes it has a great potential market. It has been made in pilot plant and is now being put into commercial production.

Two New "Super" Alloys for the Aircraft Industry.—Two new high temperature alloys for aircraft and industrial gas turbine applications have been announced by the International Nickel Company. The first, Inconel "700" * age-hardenable nickel-cobalt-chromium alloy, contains approximately 50 per cent nickel and 30 per cent cobalt. This new alloy, a modification of Inco's Inconel "X" * high temperature alloy, was developed by Inco for aircraft designers who were seeking adequate strength for forged aircraft gas turbine blades at temperatures up to 1650° F. A metal was required that could be operated at a working temperature approximately 150° F. higher than the Inconel "X" alloy.

This nickel-cobalt-chromium alloy is now produced as hot rolled rounds in the size range of ½- to 2-in. diameters —all rods are furnished with a turned or ground finish. A small amount of cold rolled sheet has been produced experimentally. The mechanical properties of the Inconel "700" alloy at 1650° F. are very similar to those of Inconel "X" at 1500° F. The new alloy has enabled aircraft engine builders to either increase the performance of the current engines or to plan the designing of future engines to operate at a higher temperature range.

The second new product, Incoloy "901" * nickel-iron-chromium alloy, has been developed for use in aircraft and industrial gas turbines for those components requiring high creep and rupture strength in the temperature range of 1000 to 1400° F. At these temperatures, the Incoloy "901" alloy has properties that compare favorably with those of the "super" alloys yet is low in strategic alloy content.

An important physical property of this new alloy is its low coefficient of thermal expansion. Containing approximately 40 per cent nickel, it is close enough to ferritic alloy steels to permit the two materials to be joined without special provision for thermal expansion. In addition to bar and forging stock, the alloy is also produced as sheet in the same sizes and gauges as those offered in Inconel "X" and Inconel "W" * age-hardenable alloys.

Incoloy "901" is expected to find wide application for use in turbine rotor and compressor discs and structural parts calling for an intermediate temperature range of 1000 to 1400° F.

Computer for Missile-Guidance Systems.—Burroughs Corporation has been under contract to the U. S. Air Force to develop and produce prototypes of an electronic computer which will be the "brains" in the guidance system for advanced missiles. Employing the newest techniques used in electronic data processing systems, including transistors and magnetic cores, the Burroughs computer will provide the means for controlling the missiles as they are propelled out into space beyond the earth's atmosphere.

Prior to launching a missile, infor-

* Trademark—The International Nickel Company, Inc.

mation concerning the planned trajectory is fed into the computer. When the missile is launched, it is tracked by radar and a constant flow of information concerning the missile's actual course, speed and altitude is transmitted to the computer automatically. Operating at speeds measured in thousandths of a second, the computer compares this information with the programmed data previously introduced. Through a radio communications system, the computer can control the speed and direction of the missile by "ordering" the changes necessary to keep it on the predetermined course toward the target. The computer is expected to guide the missile with such accuracy that it will fall close enough to the center of the target area to accomplish its purpose.

The first of the prototypes is being constructed so that it can be set up in trailers or vans for easy transportation to launching sites.

Outdoor Thermostat.—An outdoor thermostat control that tips off the indoor thermostat to changing weather conditions is now available from the General Electric Company. Developed by the company's Appliance Control Department, it is expected to cost consumers about 75 per cent less than existing automatic systems. The control helps prevent indoor temperatures from dipping with sudden outside changes providing greater comfort in the home.

Ordinarily, G-E engineers explained, a drop in outside temperature means that the homeowner is required to adjust his indoor thermostat upward to compensate for heat loss through the colder walls. The new system does this automatically, eliminating manual adjustment on the part of the homeowner.

Heart of the outdoor thermostat is a small wafer of an unusual carbon compound that senses weather changes and then sends a minute electrical signal via a 25-volt circuit to the indoor thermostat. Thus warned, the indoor thermostat turns on the furnace to cope with lower temperatures.

General Electric's Appliance Control Department is now making the device available through furnace manufacturers and distributors.

Novel Forgery Detector.—An English policeman has invented an instrument for the rapid detection of forgeries, which is also suitable for certain industrial and scientific investigations. Although not in general production, it has been officially adopted by the Criminal Investigation Department of the Worcestershire County Constabulary and by some of the forensic laboratories of Britain's Home Office.

Called the Evans Infra Red Viewer, the instrument is, in essence, a system of filters and lenses contained in a long box. Facing a four inch diameter condenser lens is a flat specimen holder. This is irradiated by a Philips 500 watt "Photolita" Photoflood lamp which contains an internal mirror reflector. The instrument is fitted with a friction-drive focussing device; a ball and socket mounting allows the specimen to be scanned horizontally and vertically. Magnification is 2.1.

The principle used is that of color-subtraction: this means that all light radiation below 7400 Angstrom Units is cut out, making visible any links which do not contain metallic ingredients. Previously, the same results could be achieved only by photographing the subject on an infra-red plate —an expensive method with the added disadvantage that infra-red plates have only a limited life and need to be kept in refrigerated store.

The viewer is not only being used for checking suspected documents, licenses, bank books and checks, but it has also been successfully used in the examination of sub-cutaneous bruising. It can also be used to reveal the quality of dyes in textiles, the presence of disease in leaves and the faking of oil paintings.

Three Dimensional Mirror.—A British engineering firm, which during World War II produced jettison fuel tanks for United States aircraft, has taken out world patents on a mirror which is claimed to give real reflection for the first time. Comprising two wings of mirror glass, set at angles to each other, it gives back the natural reflection, not the usual reversed one.

A printed page held in front of the mirror can be read normally. Already one leading New York store has made inquiries, and the London beauty salons are also showing interest. The firm is considering plans to grant licenses for the mirror's manufacture overseas.

Protective Materials.—A new substance, which improves the resistance of concrete to corrosion by mild acids that attack the cement in it, has been produced by Semtex Limited, of London, a subsidiary of the Dunlop Rubber Company, Ltd. It is a low viscosity, partially condensed resin syrup of the furane type.

The product is marketed as Furacrete, and it replaces part of the gauging water during the mixing of the concrete. When the cement is hydrated in the normal manner, the resin remains distributed until acid solutions come into contact with the concrete. These acids cause the resin to harden into a corrosion-resistant mass and dilute acids cannot then attack the concrete.

The same firm also produces Semprene, a new industrial coating for applying to mild steel, cast steel, cast iron and aluminum surfaces. The material is based on synthetic rubber. It is supplied in the form of a base coating and an accelerator, which are mixed in specified proportions before application. The rubber vulcanizes at normal temperatures, giving a tough self-adherent coating to resist corrosion.

New Metal Alloy of Unusual Properties.—THERMENOL, a "universal" alloy with some amazing properties, has been developed by the U. S. Naval Ordnance Laboratory. The metal is superior to presently used alloys for heating units in toasters, hot plates, and electric ranges. It is 20 to 25 per cent lighter than stainless steel, and possesses better tensile strength at high temperatures.

Corrosion and oxidation resistance of the new metal alloy are excellent. It also has extremely good magnetic properties which make it preferable for use in transformers and tape recorder heads.

Because of its high tensile strength even at 1200° F. temperatures, THERMENOL offers great promise as a replacement for stainless steel in the turbine blades of jet aircraft engines, in the tail pipes of jets, and for many other applications where temperature and corrosive atmospheres are a problem. The metal will indefinitely retain a mirror-like high gloss polish.

But the most important quality of THERMENOL is that it contains no strategic or critical metals—an important factor in national defense.

Explosive Bolt Releases Bombs from New High Speed Aircraft.—The Navy has announced that a Navy aircraft, employing a small lightweight

device developed by Modern Metal Crafts Company for the Bureau of Aeronautics, has successfully released a bomb while flying at Mach 1.2 (approximately 840 mph.). This is the fastest speed for a bomb drop ever recorded in level flight.

The device enables the bomb to take a routine trajectory, overcoming the tendency of the projectile to remain with the aircraft in such high speeds.

With slower speed aircraft, gravity alone was the power which separated the bomb from the airplane. But with supersonic aircraft, high speed air tends to keep the bomb against the aircraft and even after separation high speed air many times lifts the tail of the bomb so far and so rapidly that the bomb collides with the airplane. Damage to the aircraft even from an unarmed bomb is likely to be serious, but even if it is not, the collision so upsets the bomb that no prediction can be made about where it will fall.

A far reaching solution to the problem was sought. In the search, an *explosive bolt,* which is cut in half when a self-contained powder charge is ignited, was investigated. The explosive bolt has been found to offer excellent possibilities for ejecting and releasing bombs. Furthermore, the explosive bomb will be simpler, lighter, and easier to streamline than historic bomb racks.

Miniaturized Magnetic Receiver. —"Audipage"—a tiny, personal magnetic receiver developed at Philco Corporation—will be introduced during the forthcoming national political conventions and will play an important communications role in the American Broadcasting Company's nationwide television and radio coverage of the events, it has been announced.

According to the joint ABC-Philco announcement, thirty of the new devices will be included in a large-scale TV equipment field test by the two companies. Also included are four complete Philco TV studio film systems and a mobile, super-power, microwave relay system for picking up on-the-spot convention scenes.

Philco, Government & Industrial Division, engineers demonstrated "Audipage" during press conference held by that company at the National Association of Radio and Television Broadcasters Convention in Chicago. The receiver, which may be hidden in a person's garments, is about the size of a cigarette lighter. Complete with its tiny mercury storage battery, an Audipage weighs only an ounce. Sound, inaudible to anyone other than the wearer, is received through a tiny, flesh-colored earpiece.

The receiver will operate only within the restrictions of a wire "loop" strung around the perimeter of an area. An entire building, however, can be included in a "loop." According to James D. McLean, vice president and general manager of Philco's G. & I. Division, Audipage can be used, not only for TV, but for public buildings, such as hospitals, theatres, schools, libraries, etc., where conventional intercom systems are impractical.

Audipage will be used by ABC roving commentators at the Chicago Democratic convention beginning August 13 and at the San Francisco GOP convention beginning August 20. Frank Marx, ABC vice president in charge of engineering and general services, reported that Audipage will permit commentators to receive instructions directly from control points without the use of connecting wires or cables.

Philco's Audipage models utilize the company's recently announced M-1 subminiaturized transistors, believed to be the smallest such semiconductor de-

vices yet developed. Because of their tiny size, transistors are particularly suited to portable magnetic receivers. Transistors, which perform most of the functions of vacuum tubes, do not create heat, are extremely rugged, long lived and light in weight.

Television studio equipment listed in the ABC-Philco national conventions field tests, will include two 35-mm. CineScanner systems and two 16-mm. CineScanner systems with associated power equipment. Philco CineScanner film systems, which feature "cold" light and continuous film motion, will be used by ABC for film clips and rebroadcast of convention highlights. Portable microwave relay equipment will be used by the network on its mobile unit. Two-foot antenna "dishes" are included.

Unique Fastening Tool.—Olin Mathieson Chemical Corporation has introduced a multi-use, manually-powered fastening tool, described as "the greatest single forward step in fastening since the introduction of the powder-actuated tool just after World War II" by a divisional executive of the company.

The tool is called Shure-Set, and it will ease the light fastening work for millions of craftsmen. Sold by Ramset Fastening System, Cleveland, a part of Olin Mathieson, it is the first tool of its type to be manufactured in the United States. With this fastening device, for the first time a worker can manually drive a fastener through one-quarter-inch steel.

"Shure-Set brings to a wide area of fastening work a mid-Twentieth Century tool and ends the dependence of the worker on less efficient, old-fashioned fastening methods," Clarke Tryon, Ramset sales manager, declared. "The new tool also means that the working man can do his job more efficiently while carrying fewer tools. It has so many uses that in construction we sell it for around-the-building fastening work."

It is a well-known fact that a needle can be driven through a coin if it first goes through a cork. It is the support of the pin by the cork that makes this possible, Mr. Tryon pointed out. The tool works on the same principle. Proper support of the pin means maximum utilization of the energy expended in swinging the hammer.

The new tool seats a specially-constructed fastener into a variety of materials such as concrete, concrete block, cinder block, brick and steel. It ends the need for such fastening devices as toggle bolts, expansion shields, anchors, and concrete nails. It eliminates the tedious job of star drilling.

The tool is capable of using a variety of fasteners in the $\frac{1}{4}$-in. and $\frac{3}{16}$-in. sizes, and changeover from one to the other is simple. It fastens into a variety of materials and assures that the fastener will be placed precisely where the worker wants it. The point of the fastener is put on a precise spot and stays there during the hammering. With Shure-Set a worker can place up to 150 fasteners in an hour!

Special fasteners were developed in conjunction with the new tool. Manufactured by an exclusive heat-treating process called Austempering, they have a maximum of toughness and hardness to assure clean and simple penetration. Drive pins range from $\frac{3}{4}$ in. to 3 in. in length, while threaded studs are from $\frac{3}{4}$ in. to $\frac{2}{3}$ in. in length with varying length shanks.

The tool can be used by such diverse craftsmen as electricians, general contractors, lathers and plasterers, plumbers, sheet metal workers, carpenters, maintenance men, interior decorators, sign painters, telephone companies, and to install plant protection systems.

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA

welcomes as members all those interested in its purposes and its activities

ANNUAL MEMBERS

Sustaining	$50.00
Active Family	20.00
Active	15.00
Active Non-Resident (50 miles or more from Philadelphia)	7.50
Associate Family	10.00
Associate	5.00
Student (14 to 25), with Library privileges	3.00
Student (under 25), without Library privileges	2.00

LIFE MEMBERS

Active	$300.00
Active Non-Resident (50 miles or more from Philadelphia)	100.00
Associate	100.00

PRIVILEGES

Free admission to the Museum, Planetarium, and Institute Lectures is granted to all members and to the families of Sustaining, Active Family, and Associate Family members.

The Institute News, which includes news items about the Institute as well as announcements of meetings and lectures, is sent to all members.

The *Journal of The Franklin Institute* is sent to Sustaining, Active Life, Active Family, and Active members.

Use of the Library is granted to Sustaining, Active Family, Active, and Active Non-Resident, as well as to the $3.00 Student members.

THE FRANKLIN INSTITUTE **Benjamin Franklin Parkway, Philadelphia 3, Pa.**

Gentlemen: I desire to contribute to the work of The Franklin Institute by enrolling as ..... Member, for which I enclose payment of $..... the amount due per annum.

NAME .....
(Please Print)

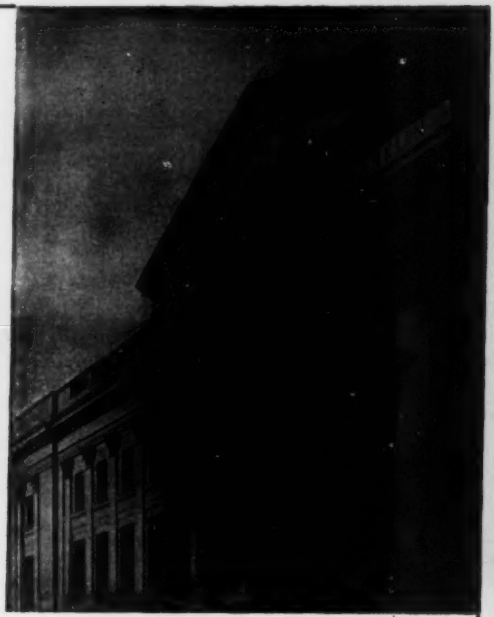
ADDRESS .....

.....

.....

SIGNATURE .....

The Franklin Institute Laboratories for Research and Development



One of the nation's largest industrial research laboratories

Where a fully qualified staff of engineers and scientists works as a competent and versatile research team—bringing a fresh scientific approach to problems of materials, methods and machines of modern industry.

in the fields of

Chemistry and Physics • **Electrical Engineering**
Mechanical Engineering • **Solid State Physics**

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA

BENJAMIN FRANKLIN PARKWAY AT 20TH PHILADELPHIA 3, PA.